ELECTRIFICATION PROJECT OF THE CHICAGO SUBURBAN SERVICE C. B. & Q. R. R.

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OF THE

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A THESIS

PRESENTED BY

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INTRODUCTION.

INTRODUCTION.

Complaints are constantly registered against the nuisances accruing to the operation of steam railroads within the city limits. The City of Chicago has recently made an investigation of the "Electrification of Terminqls", with the view of forcing a change from steam to electric operation of the trunk lines now entering the city. The Chicago Burlington and Quincy R. R. is one of these lines, and it is the purpose of the writers to investigate the feasibility of its electrification, and to present a report on the cost of the change, together with a complete determination of the electrical equipement.

PART I.

GENERAL REPORT.

EXTENT OF THE ELECTRIC ZONE.

It is proposed to incorporate the complete suburban service of the C. B. & Q. R. R. in the electrification project. This extends to Aurora, Ill., 37.4 miles from the Union Station at Canal and Adams Sts., Chicago. (See Map and Profile, Fig. I & II.) Under the present steam service, trains are operated to three terminals, Riverside (11.1 mi.), Downers Grove (21.2 mi.), and Aurora (37.4 mi.). From Chicago to Western Ave. (3.8), the C. B. & Q. R. R. operates over the right of way of the Pennsylvania R. R. From Western Ave. to Clyde, (8.5 mi. from Chicago) there are four tracks. From Clyde to a point just west of Downers Grove (13.5 mi.), there are three tracks, and thence to Aurora, two tracks. On the four track section, one is used for freight exclusively; thus 22 miles of three track road, and 15.4 miles of double track road, or 96.6 miles of single track, will be electrified. On the four track section, the strut bridge for supporting the

trolley will span all four tracks, so that an additional trolley can be installed at any time at low expense for future electric handling of freight.

GENERAL SCHEME OF ELECTRIFICATION.

It is proposed to build a power plant of 6000 K.W. capacity at Riverside, 11.1 miles from Chicago, and 26.3 miles from Aurora, at what is practically the center of the load. Power will be generated at 11000 volts and fed directly to the trolly. The maximum voltage drop is about 10 %. The high tension trolly section will extend from Western Ave. to Aurora, 33.6 miles. From Chicago to Western Ave. (3.8 mi.) 1200 volts A.C. will be used on the trolly. Two substations, transforming from 11000 to 1200 volts, of 1000 K.W. capacity each, located .65 miles and 3.15 miles, respectively, from Union Station, will handle the power for this section. The following data sheet gives a complete summary of the road and equipement.

Multiple unit train operation, with a standard three car train, half hourly service to Riverside and Downers Grove and hourly service to Aurora are proposed.

ELECTRIC RAILWAYS

NAME OF COMPANY CHICAGO, BURLINGTON and QUINCY R.R. DIVISION CHICAGO

MILEAGE: Road 37.4 City 0 Interurban Total miles track
Private Way 37.4 Highway 0 Single track Double track

POPULATION: Per mile road Per mile total track Pop. of terminal 2,000,000

TRAIN SERVICE: Limited Local Freight Express
No. cars per train 3 - 5 3 - 5
No. stops per mile
Schedule Speed
Maximum Speed 62 m.p.h. 62 m.p.h.
Headway 1 hr. 1/2 hr.
Motor cars per train all all

PERMANENT WAY: Av. width Max. Grade .86% Curves 750′ of 12°
Roadbed: Width Ballast Rock, gravel Bridges
Track: Gauge 4′ - 8 1/2″
Rails: Section T Length 33′ Wt. per yd. 70#, 80#, Joints
Ties: Size Material Center distance
Bonds: Type Capacity 4-0 Length 2 Number per joint
Where applied Cross bonds: size 4-0 1000 ft. apar
Signal System:

TERMINALS AND STATIONS: Chicago, Riverside, Downers Grove, Aurora

Shops and car barns Riverside, Downers Grove Aurora

ROLLING STOCK:
Type Passenger Number 65 Mfg. body Total wt. unloaded 96000#

Carbody: Length overall 60′ Length body 48′ Truck cen. 36′-6″ Couple
Width overall 9′-6″ No. compartments 1 and 2 Seating capacity 62, 48,
Height to roof 13′-0″ Length comp. Color body
Trucks: Type Mfg. Wt. M-15000 T-10000 Wheel base
Wheels: Type Rolled Steel Diam. 38″ Width tread 3 1/2″ Width flange 1″
Depth flange
Axles: Center diam. Wheel seat diam. Size journals
Equipment:
2 Motors Wgh. #156 (150 h.p.) Gear ratio 2.86 Accel. .9mphps. Lubrication
Control system Electro-pneumatic multiple
Braking system Automatic air
Heating Electric

GENERATION AND TRANSMISSION:
Power House: Location Riverside Total capacity 6000K.W. See Sheet No.
High Tension Transmission: Volts 11000 Phase 1 25 ~ Longest transmission
Av. dist. between sub stations Where located Span 300′
Sub Stations: 2
Step down transformers 2-500K.W. selfcooling in each. Connections
Rotaries Reactance
Switching Storage battery
Low Voltage Distribution:
Trolley: volts 11000, 1200 Dist. bet. taps Third Rail: Volts
Size 3-0 Form Grooved Height 22′ Wt. Section
Suspension: Type Span Center to gauge line
Catenary: Type Single Height above track rail
Size of messenger 7/16″ Insulators; type
Feeders Dist. apart
Type pole line Length span Bonding type capacity

1200 volts used from Western Av. to Union Station.

Recorder

COST ESTIMATES.

It is estimated that the Chicago suburban service of the C. B. & Q. R. R. can be electrified at an expenditure of $2,000,000. This estimate has been worked out with the general scheme of electrification, outlined in the foregoing, as a basis.

The valuation of the power plant is placed at $95 per K.W. This general value had to be taken, owing to the imposibility of students obtaining accurate cost estimates from the manufacturers.

The cost per car is taken at $11600. This estimate is made from the following:-

Cost per car on weight basis.

Motor. 6 tons at $625	$3750
Auxiliary equipment. 10 tons at $125	1250
Trucks. 13 tons at $220.	2860
Car bodies. 18 tons at $85	1530
Labor in assembling. 48 tons at $35	1680
Total cost	$11070

An estimate of car cost was also made as follows:-

Total cost D.C. Multiple Unit cars used on Melrose Div. N. Y. N. H. & H. R. R.	$10,500
Excess cost A.C. motor equipement.	1,000
Auto-transformer. 250 K.W. at$3.oo	750
Total	$12,250
Average of two estimates.	$11,600

Two substations are required, 1000 K.W. each with an ultimate capacity of 1500 K.W. At $4 per K.W., $9,000 should cover the cost of two buildings and the 2,000 K.W. of transformer equipement.

The estimate of cost of trolly construction, using strut bridges, (Fig. 18) spaced 278 ft. apart is as follows.

High Tension Trolly Material.

Trolly material / mile	$400
Wire and cable (not trolly) / mile	300
2687# - 3 - 0 trolley at 15 c.	403
Labor, excluding bridges.	800
Cost / mi. single track	$1903

14.8 mi. double & 18.8 mi three

track road at $1903 / mi.	$164,000
Feeder	3,000

Low Tension Trolly Material, etc,

Trolly material.	$400
3381# - 4 - 0 trolly at 15c.	507
Wire and cable	300
Labor	800
Cost per mile single track	$2007
3.8 miles (4 track trolly) - 15.2 mi. single track	$30,600

Bridges, including erection and foundation.

Two track span.

6400# steel at 3c.	$192
2 2/3 cu. yds concrete at $6.	8
Total.	$200

Three track span.

7600# steel at 3c.	$228
Foundation.	8
Total	$236

Four track span.

New Haven type	$750

252 - 2 track bridges at $200 (14.8 mi. 19 per mile.)	$56,400
14.4 triple track bridges 268 at $236	63,300
8.5 mi. four track bridges. 162 at $750	121,200
Total	$240,900

Bonding 80# rail, 86 mi. single rail. High tension. 30250 4/0 at $.40	$12,100
Bonding 80# rail, 11.2 mi. single rail. Low tension. 3 - 4/0 per joint. 6025 at #.40	$ 2,500

Summing up the various estimates, the following is the completed estimate for the cost of this project.

High tension trolly	$164,000
Low tension trolly.	30,600
Feeder	3,240
Bridges	240,900
65 cars. at $11,600	755,000

Rail bonds.	14,600
Total.	$1,208,340
Engineer and superintendence 10 %	120,000
57 sectionalizing circuits breakers at $160	9,120
Power plant	570,000
Total	$1,907,460

PART II.

ENGINEERING DETAILS.

DETERMINATION OF SYSTEM.

DETERMINATION OF SYSTEM.

The choice of system resolves itself into a question of cost and reliability. Both alternating and direct current installations have proved sufficiently reliable for trunk line operation. The choice then, rests on the comparative costs of installation.

Below is itemized the cost of each system exclusive of the cost common to both.

Alternating Current System.

96 mi. single track at $1000 excess / mile.	$96,000
65 cars at $1000 excess apiece.	65,000
Total	$161,000

1200 Volt Direct Current System.

75 mi. #4 copper wire for 3 phase transmission lines	$7,500
3 phase transmission line material 25 mi. at $450	13,500

Step up transformers, 4000 K.W. at $3.oo	$12,000
Step down transformers, 6000 K.W. at $4.oo	24,000
Converters. 6000 K.W. at $17.	102,000
Auxiliary apparatus.	4,000
Oil switches at substation,12 at $1000	12,000
Investment equivalent to operator salary charges.	13,300
Total	$188,300

This comparison favours the 11000 volt alternating current system by $27,300. Summing up the above, the conclusion has been reached that alternating current should be used on the trolley. However, a more careful and complete investigation, than is possible in the limited time allowed for this thesis, might prove that a 1200 volt, third rail system would possess such advantages as to make it advisable to install such a system.

DETERMINATION
of
MOTOR EQUIPEMENT.

Source of Motive Power.

The queston here presents itself as to whether motor cars, with multiple unit control, or electric locomotives shall be used to supply the motive power. For suburban service, such as this, where trains of from one to five cars are operated, and long trains are the exception rather than the rule, the advisability of having each car a motor car is most forcibly brought to the fore. The greatest good to be derived from electric operation is the splitting up of the seven and eight car trains,as now in vogue under steam operation,into several divisions consisting of three cars each, thus decreasing the headway and operating a better service with the same amount of rolling stock. Under these circumstances, electric locomotives are discarded as a possible source of motive power for this project, and the motor equipement has been determined considering a typical train as composed

of three motor cars.

Preliminary Engineering in Determination of Motor Equipment.

The determination of the motor equipment for a given railway service implies a fore-knowlege of the composition of trains, weight of motor car and trailers (if used) the profile of the road, and its alignment.

Composition of Trains.

Under steam operation the typical train is 4.4 cars per train. Under electric operation it is proposed to run mostly three car trains, and one one car shuttle train between Riverside and Downers Grove. The typical train under these conditions is taken as three cars per train.

Details of Proposed Car.

The general design of the proposed motor cars are shown in Figs. 3. and 4. The

length of the cars, of both types, passenger and combination passenger and baggage, is 60 ft. The advantages of cars of this length as compared with shorter cars,for a service such as this,are so self evident as to need no elucidation. Motor cars larger than 60 ft. are seldom used, and this length has been decided upon as conforming with interurban practice, which is closely approximated by this service. The seating capacity of the passenger cars is 62, that of the combination,48. Hinged seats are provided in the baggage compartment, which add a seating capacity of 6 to the combination cars. The seats near the doors are of the side type, so as to increase the standing capacity.

Trap doors are provided on the platforms to allow for double ended operation and to increase the standing space. Swinging doors are located in the front of the vestibule to allow movement of passengers between ad-

joining cars.

The weight of these cars, include motor equipment, is 48 tons based upon the following itimized weights.

Wt. Motor truck.	15000	lbs
" Trailer truck.	10000	"
" Aux. Electrical Equip.	14000	"
" Car body.	37000	"
" Air Brake.	2000	"
" Motor driven compressor	2000	"
" Forced vent. compressor	1000	"
" 2 - W. 156 motors.	14900	"
Total wt. empty	95900	"
Or	48	tons
Wt. Passengers 60 at 150#	9000	lbs
Total	104900	lbs

In figuring train characteristics account must be taken of the retarding effect due to rotational inertia of the moving parts. Allowing 7 % of the weight (loaded) for this the total weight accelerated, using two Westinghouse #156 motors per car, becomes

56 tons.

SELECTION OF MOTORS.

There are four motors on the market which have had extended use in single-phase electric traction, namely, Westinghouse #148 A (125 HP.) and #133 or #156 (150 HP.) and General Electric #605 (75 HP.) and #603 (125 HP) . The characteristics of W.148A and 133 are shown on curfe sheets No. 5 to 10. inclusive.

Five hundred H. P. equipements are quite popular on high speed interurban roads, or where track conditions are such as to warrent the distribution of the tractive effort to two trucks, which can be obtained by using four 125 HP. motors. The maximum speed required in this project is but 60 mi. per hr., while the track conditions are about ideal. Therefore no advantage would be obtained from a four motor 500 HP. equipment, except a rapid acceleration. On the other hand, the increase in weight of the motors alone is sufficient to considerably

increase the energy consumption, thus lowering the efficiency of each car unit. A careful investigation has proven that 300 HP. divided between two motors will give an acceleration of .9 miles per hour per second, and a maximum speed of 62 miles per hour. This fulfills all the conditions imposed on the system, at the same time keeping the temperature of the motors well within the limits of the rating. A four motor, 300 HP. equipment has not beem considered, because of the disadvantage resulting from the additional weight of the extra motors.

A two motor, 250 HP. equipment was investigated, but not considered in detail, for it required a gear ratio of 4 to 1 to obtain an acceleration of1mi. per hr. per sec. and a maximum speed of 56 mi. per hr.

The results of this preliminary investigation was a complete study of just one equipment, namely two Westinghouse #133 railway motors or #156, which has the same rating

as #133 but uses the quill suspension. Curves #11 to 16 show the preliminary and detailed investigations made in connection therewith. The gear ratio study proved 66/23 = 2.86 to be the most efficient gear ratio. It is intended to use forced ventilation with this motor, so that at any time the motor capacity can be increased by merely incfeasing the flow of air. There will also be provided a high speed notch on the controller, which will increase the voltage at the motors whenever it becomes necessary to make up time.

Speed, current, current squared, apparent power, real power and voltage for W #133 motor are plotted against time on Curve sheet #15, from which the train characteristics, as shown in Curve Sheet #16, were determined, and also the schedule laid out.

The graphical time table (Figs. 20 & 21) convey the idea of the general schedule which it is proposed to follow under electric operation. Hourly service is to be established between Chicago and Aurora,

stops being made at Hinsdale and all stations between Downers Grove and Aurora. Hourly service will also be maintained on the Downers Grove run, making stops at Berwyn and all stations between Riverside and Downers Grove. Trains making all stops on the Riverside run will likewise be operated hourly, and will be met by a single car shuttle train, operating between Riverside and Downers Grove, for conveying passengers to stations between these points. At Downers Grome, this shuttle train likewise meets the Auror express and thus affords a means of transportation between Auror and points intermediate between Downers Grove and Chicago, without interfering with the strictly express character of the trains on the Aurora run. This arangement results in hourly service to Aurora and half hourly service to Berwyn, Riverside, Hinsdale, and Downers Grove, and hourly service to all other stations. The shuttle train may be considered

as strictly interurban, providing a means of travel between Aurora and stations west of Riverside, and but slightly increasing the class of service into Chicago, though a saving of time may be affected by transferring from this train to the regular trains at Riverside instead of waiting for the regular through train.

In order to determine the error involved in assuming the road bed level, the run sheet from Western Ave. to Hawthorne, wherin occurs the maximum grade, was plotted, and the time to make the run compared with that under the above assumption, This run sheet is shown in Curve sheet #14. The error was but 7 seconds, bearing out the correctness of the asumption made.

SELECTION OF VOLTAGE.

SELECTION OF VOLTAGE.

Two standard voltages are in use on present installations, namely, 6600 and 11000 volts. The power plant of the road is located at Riverside, necessitating transmission for 26.3 miles to Aurora. For a preliminary estimate, a five car train was considered as starting at Aurora. This would take 1500 HP or 170 amperes at 6600 volts. The drop for this load, using 4 - 0 trolly , was found to be 1210 volts or 18.4 %. This load is by no means the maximum load that can be found, while the drop is excessive, 10 % being considered the maximum allowable for single phase lines. Thus the question resolves itself into one of 6600 volts with substations or 11000 volts without substations.

For the 11000 volt system, sectionalization is necessary so that one track of one section can be cut out, due to a ground or some other fault, without cutting out the entire line. The lengths of the sections

should vary approximately inversely with the traffic on the section. For this reason the sections are made long at the Aurora end and short at the city end. The section from Western Ave. to the Union Station will be, in the 11000 volt consideration, disregarded, as this section will have to be operated at a lower voltage owing to low bridges and other difficulties. The section points decided upon were,- Western Ave, Morton Park, Riverside, Western Springs, Downers Grove, Naperville and Aurora as shown on the sectionalization layout (Fig. 17A.) Starting from Western Ave. the lengths of the sections are, 3.7 mi, 3.6 mi, 4.3,mi, 5.8 mi, 7.3 mi, and 8.9 mi.

As the drop at Aurora is very liable to be greater than the drop at Western Ave. points on the load curve were selected which were not maximum points but which gave maximum loads at the Aurora end. This gave the extreme conditions. The drops were then

figured for these points. The method used for determining the drop per section was as follows. The division of load between trollys for trains in the section was found. The current transmitted to the next section was considered as dividing equally between the trolly wires and so superimposed upon the other current. The drop was then found by multiplying the current in the unloaded trolly (easiest to work with) by the length of the section and the volts drop per mile per ampere. The power taken by trains east of Western Ave was taken into consideration as being carried by the trolly east of Western Ave. An average of experimental results for voltage drop on single phase lines showed a value of 0.62 volts per mile per ampere to be about correct. The result obtained upon this basis are shown in the following,-

7.oo P.M.

Drop from Naperville to Aurora.

Current per trolly = 136.4/2

Drop = 68.2 X .62 X 8.9 = 376 volts

Drop from Downers Grove to Naperville.

Current per trolly = 136.4/2 + 4.5

Drop = 72.2 X .62 X 7.3 = 332 volts

Drop from Western Springs to Downers Grove.

Current per trolly = 181.2/3 + 5.22

Drop = 65.22 X .62 X 5.8 = 236 volts

Drop from Riverside to Western Springs.

Current per trolly = 246.4/3

Drop = 82.07 X .62 X 4.3 = 218.6 Vs.

Total drop from Power House to

Aurora = 1162.6 Vs.

Per cent drop - 10.57 %.

Drop from Riverside to Morton Park.

Current per trolly = 251.8/3 + 14.5

Drop = 98.44 X .62 X 3.6 = 220 volts

Drop from Morton Park to Western Ave.

Current per trolly = 251.8/3

Drop = 83.9 X .62 X 3.7 = 192.5 vos.

Total drop to Western Ave.	412.5 vs.
Per cent drop	3.75 %

7.30 P.M.

Total drop to Aurora	8.7 %
Total drop to Western Ave.	3.5 %

6.oo A.M.

Total drop to Aurora.	8.3 %

From these figures it can be seen that the maximum drop encountered agrees very closely with the value usually allowed. This shows that with a trolly voltage of 11000, the road can be operated without substations (except in low tension section.).

Having decided this question, the next thing to be considered is the low tension section. Direct current was considered for this section but was not found practicable. If direct current at 600 volts were used the current would be too large to handle

with a trolly and a third rail would cost too much through the yards. No higher voltage tham 600 could be used because the motors will not stand higher than 300 volts and there are only two per car.

Having found direct current unsuitable, 800 volts A.C. was considered. The drop was found to be excessive. It was then decided to use 1200 volts A.C. with two substations. The substations were placed .65 miles from each end of the low tension section. In calculating the drop for the low tension section, that caused by a five car train starting from the Union Station was considered as the maximum probable while the maximum possible (not, however,probable) was that caused by one four car and one three car train starting at 16 th. and Canal Sts. (from timetable). The first condition caused a drop of 16.3 % while the second condition caused a drop of 16.9 %. Both of these values are within the allowable limits so

that the system as selected is suitable for the conditions. When considering these voltage drops, the drop in the transmission line (high tension trolly drop) must be added to give the total drop.. This drop amounts to about 5 %,as a maximum,giving a total drop, on the lowtension section,of about 22 %, providing that the maximums occur at the same time.

One of the features of this distribution system is that no feeders were necessary, the sectionalization being done between trollys, Thus on the two track section, one trolly wire acts as a feeder for the sectionalizing of the others. Fig. 17A shows graphically the sectionalization scheme.

OVERHEAD EQUIPMENT.

OVERHEAD EQUIPMENT.

For a high speed single phase line, catenary construction is the only possible trolly construction for two reasons. For high speed work, the trolly wire must be at a uniform height above the rail, for satisfactory operation. With catenary construction, longer spans and better insulation are possible, than with simple span construction. While nothing but catenary construction enters the question, there are two types of this construction possible, namely, single and double catenary. Double catenary construction is very strong and therefore reliable in that respect, but it is very rigid. For this latter reason, it does not give very satisfactory service. The results of using this system can be seen by studying the troubles of the New Haven System. From the results obtained on that system it seems that there is little to recommend its use elsewhere. Single catenary construction is very flexi-

ble and gives, under pressure from the pantograph. It was therefore decided to use single catenary construction.

A study was then made of various single catenary installations, especially of the test track of the Pennsylvania R. R. on Long Island. A distance between supports of about 280 feet was chosen. This span gives ninteen bridges per mile. A light bridge (Fig. 18) was selected for the two track section. This bridge was designed along similar lines to that used on the Pennsylvania test track. It is proposed to install a heavy anchor. bridge evry mile to keep the construction fairly rigid longitudinally. On curves, special construction will be used. A design of this bridge is given here. This same form of bridge is used for the three track section, where only three tracks are spanned, but where four tracks are spanned, a special heavier bridge is necessary. No design is given for this bridge, but a bridge is to be used of the type used by the N. Y. N. H. & H. R. R.

It was decided not to place circuit breakers and other sectionalizing apparatus on the bridges, on account of the trouble encountered by the N. Y. N. H. & H. R. R. due to sleet and snow. A small house is, therefore, provided to enclose the apparatus at section points. This puts the apparatus in a position where it is easily available in case of trouble and avoids all trouble from weather.

A 3/8" stranded steel mesenger cable will be supported on insulators at the bridges. Suspended from this will be a copper trolly wire of 3 - 0 cross section area. After deciding these points, the question of using a secondry trolly presents itself. The question is really this; experience has shown that a secondry trolly must be provided to take the shocks or else a bow trolly must be used. This bow trolly may be used with a pantograph trolly, if desired, the former taking care of small changes in height of

trolly and the latter taking care of the large changes. There are bound to be slight changes in the height of the wires due to sag. Experience has shown that a pantograph with heavy moving parts wears a trolly wire, at the points of suspension, by delivering a blow to the wire. ON THE N. Y. N. H. & H. R. R. where rigid suspension was used, the pantograph would pick up the sag in a section and carry it to the next point of support, where it would literally tie the wire into a knot. With less rigid construction, this trouble would be less pronounced, but still the trouble is there, so that it seems advisable to use a secondry trolly wire. This wire is to be a solid steel section of area about 3 - 0. It is to be suspended from the copper or conductor wire by hangers of the design shown in Fig. 19. This wire will take all of the wear and keep the conducting wire of full cross-section. This abolishes the necessity of a bow trolly or bow attachment.

The construction on the low tension section is the same as on the high tension except the copper trolly is of 4 - 0 area.

POWER PLANT.

POWER PLANT.

After deciding on the voltage to be used and the amount of power necessary, the next consideration was that of the method of generation. Three phase and single phase systems were considered. The effect of dividing the line into two sections and connecting the trolly of each to one phase wire and connecting the single return to the third wire, was considered both with a delta and star connected generators. Experiments were performed to determine the results of such a connection and it was found, with the generator used, that unbalanced loads meant unbalanced loads on the generator windings accompanied by voltage unbalance and change in the phase angle with serious unbalancing. These facts seemed to indicate the advisability of using single phase, and the fact that no such system as either considered above has ever been used, clinched the argument.

After deciding to use single phase dis-

tribution, the question of taking the power from a single phase or a three phase generator was considered. In many installatins the single phase power is taken from one phase of a three phase generator, the other two phases being idle,except for a small three phase power load in the station. Such an arrangement is used in the power plant for the St Clair tunnel and for the Chicago Lake Shore & South Bend Railways. In other plants single phase generators are used. The New York, New Haven & Hartford R. R. used three phase generators,but had considerable trouble with them,and so replaced most of their machines with single phase. In view of these facts and of the fact that no three phase power is really necessary, single phase generators were decided upon.

As no substations are necessary and so no high transmission voltage, it was decided to generate at the trolly voltage, thereby dispensing with step up transformers. This

greatly increases the reliability of the service. The generators were provided with impedance coils similar to those installed on the N. Y. N. H. & H. R. R. The coils take the shock due to short circuits, thus releiving the generators of a considerable strain. These impedances are provided with a relay operated short circuit so that on normal operation they are short circuited, but, at a predetermined value of current, the relay opens the short circuit and the impedance becomes effective.

The mechanical equipment of plant is covered by the accompanying form which is filled out. The methods used in designing the plant were similar to those in common practice and so need not be discussed in detail here. Figs. 23-4-5-6 shows the design of the plant.

The substations used (Fig.22) are of a standard type. They are built for an ultimate capacity of 3 - 500 K.W. transformers with a present equipment of 2 - 500 K.W.

transformers. The feeders to the substation are connected to the 11000 volt trolly at Western Ave. Oil switches are provided on the high tension side of the transformers and cut-out switches on the low tension. The feeders are protected with electrolytic arresters in the substations. The transformers are oil insulated and air cooled. They are mounted on wheels so that they can be removed easily in case of accident.

Armour Institute of Technology Branch, American Institute of Electrical Engineers 1909 Data Committee

STEAM ELECTRIC POWER PLANTS

COMPANY: C.B.& Q. R.R. NAME OF PLANT RIVERSIDE.
Location Riverside, Ill. K. W. Output 6000 Supplies power to Railway

BUILDING:
Size boiler room 135'x61' Size engine room 135'x52' Outside dimen. of bldg. 135'x134'
Ultimate capacity boiler room 4200h.p. Present capacity boiler room 4200 h.p.
Ultimate capacity engine room 6000k.w. Present capacity engine room 6000 k.w.
Type boiler room Unit system Type engine room Unit system Construction of bldg.
Cranes Number 1 Capacity 30 ton Span 52'

BOILERS:
Type B and W Number 12 Sq. ft. heating surface each 4375 Grate surfaces 87.5
Pressure 160# Degrees superheat 100° Area superheater
Type stoker Coal used Illinois

FEED WATER:
Source Desplaines River Quality Fair Temp. entering boiler
Pumps, Number 4 Type Snow Size 8 h.p. Capacity 120 gal/min
Heaters,
Ejectors,
Purifiers,
Economizer,

DRAFT:
Method,
Blowers, Number Size Type Capacity
Chimney, Number 2 Material Steel Height 125' Inside area 81□' Diam. 9'
Dimensions foundation Breeching area

COAL AND ASH HANDLING:
Method of coal handling Conveyors
Method of ash handling Conveyors
Conveyors Number 4 Type Bucket Capacity
Storage bins Where located Over boilers Total capacity 10 days supply

PRIME MOVERS: Westinghouse Parsons
Type Turbines Number 4 H. P. R. P. M. 750 Overload H. P.
Water rate full load Size bearings

CONDENSERS:
Number 4 Type Surface Vacuum 28 in. Sq. ft. surface 2500
Temp. of water supply 70°F Temp. discharge 90°F

Pumps	Wet	Dry	Combined	Circulating
Number			4	4
Type			Duplex	Centrifugal
Size				16 h.p.
Capacity			170 cu.ft./min	575 cu.ft./min.

PIPING: Type
Sizes: Boiler connection Main Header Engine connection

GENERATORS:
Number 4 Type Turbo Volts 11000 K. W. 1500 Cycles 25 Phase 1
Speed 750 Efficiency Overload capacity
No. poles 4 Diam. rotor Size bearings

EXCITERS:
Number 4 Type Motor K. W. 45 Volts 100 R. P. M.

TRANSFORMERS:
Number 2 Type Selfcooled K. W. 90 Volts 220 Phase 1
Method of connection Method of cooling

SWITCHING: Trolley and feeders tied to buses through remote control oil switches. Generator, transformer, and station panels in gallery. Feeder panels in switch house. Exciter panels on engine room floor.

Recorder

LIGHTNING PROTECTION.

LIGHTNING PROTECTION.

The generators are thoroughly protected by arresters installed in the power house as shown in the wiring diagram (Fig. 26). The substation apparatus is also protected by arresters installed in the station.

There is no high tension transmission line to protect so that the only thing remaining is to protect the trolley line and the cars. The cars are protected by installing an arrester on each one. The line is protected by installing a fuse type arrester on every fourth bridge (1390) ft.) The bridges are thoroughly grounded to prevent accidents due to charged bridges.

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Spokane and Inland Ry.	S.R.J.	Aug.25,1906 Sept. 1906 Apr.27,1906
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Service Capacity of Railway Motors.	S.R.J.	Apr. 6,1906
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MAPS, CURVES, AND FIGURES.

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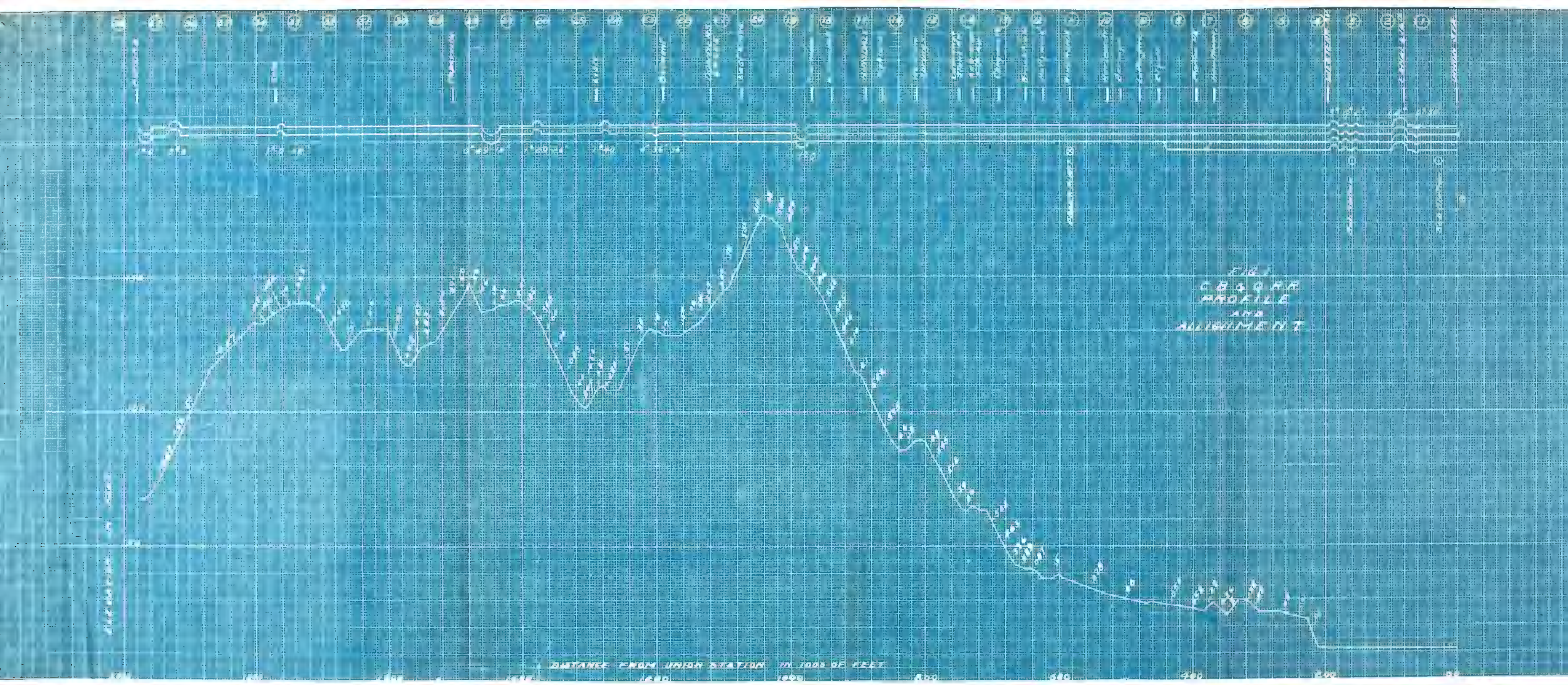


FIG. 1
C. B. & Q. R.R.
PROFILE
AND
ALIGNMENT

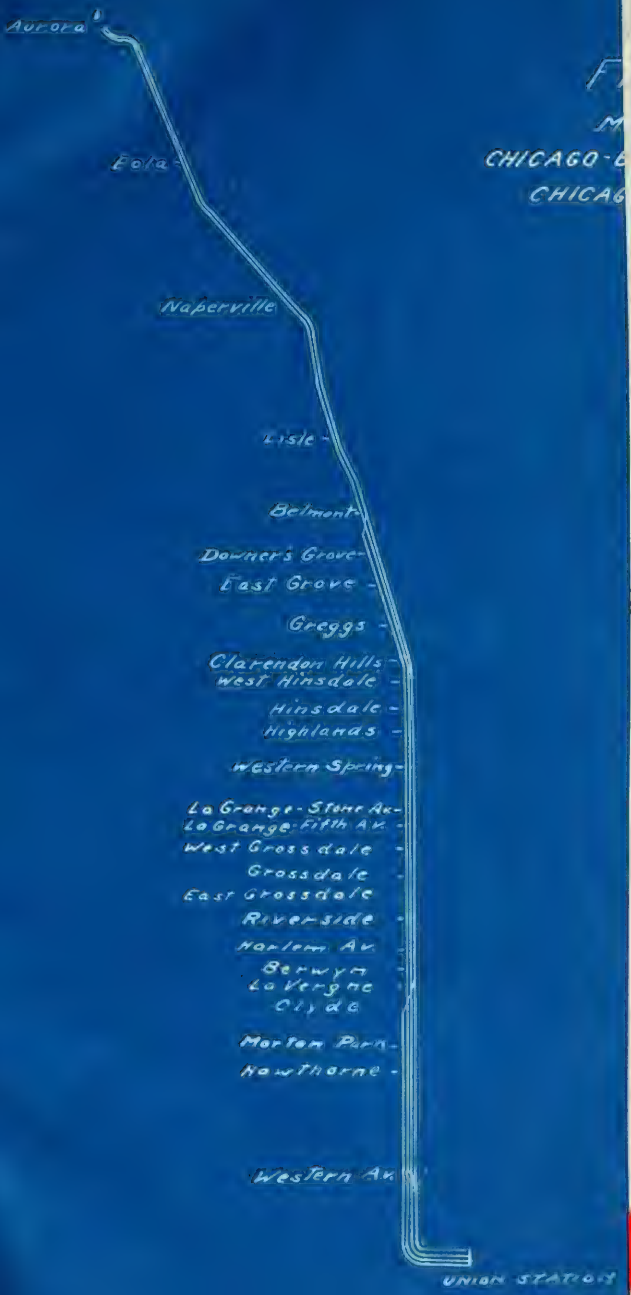
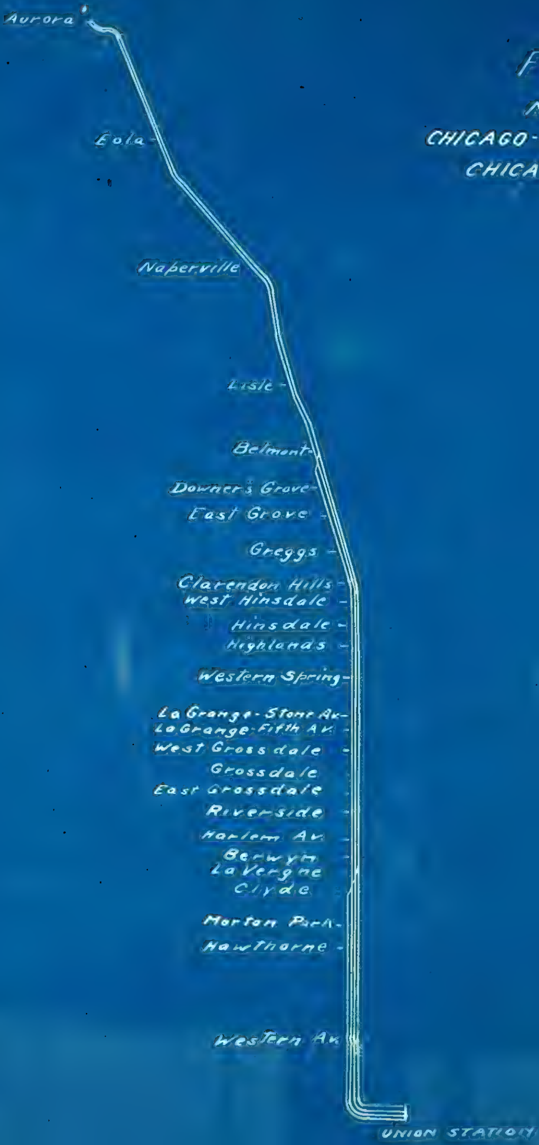
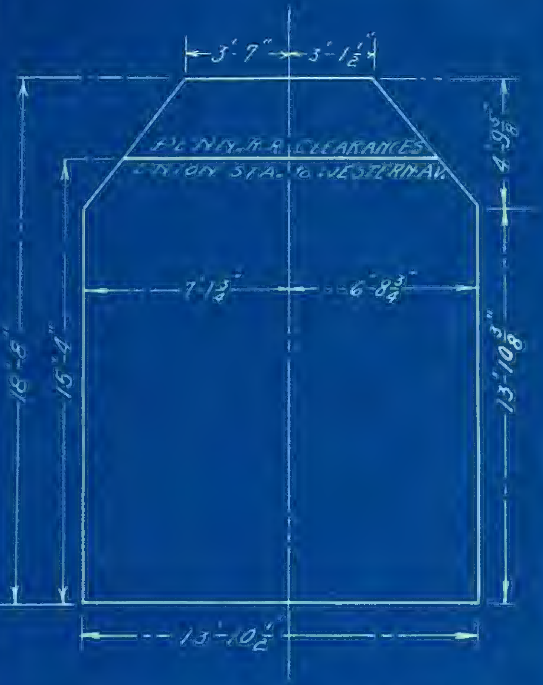

F
M
CHICAGO-
CHICAG
Aurora
Eola
Naperville
Lisle
Belmont
Downers Grove
East Grove
Greggs
Clarendon Hills
West Hinsdale
Hinsdale
Highlands
Western Spring
La Grange-Stone Av.
La Grange-Fifth Av.
West Grossdale
Grossdale
East Grossdale
Riverside
Harlem Av.
Berwyn
La Vergne
Clyde
Morton Park
Hawthorne
Western Av.
UNION STATION

FIG. II

MAP OF
CHICAGO-BURLINGTON & QUINCY.
CHICAGO TO AURORA

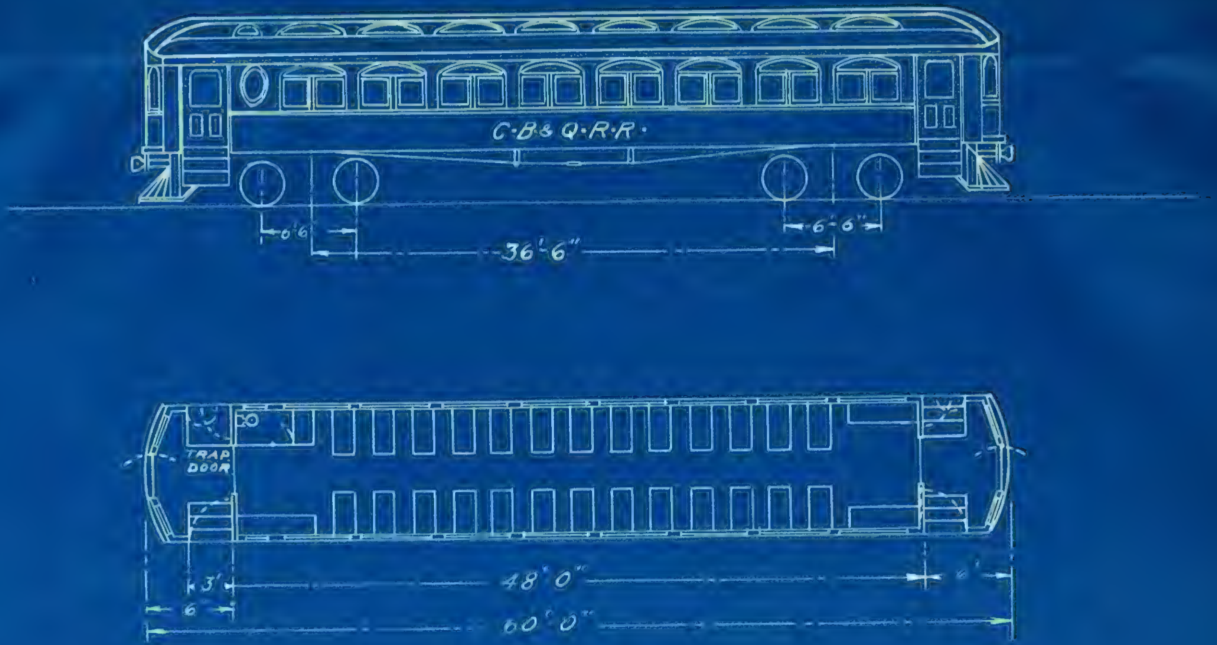




MINIMUM CLEARANCES
BETWEEN
CHICAGO AND AURORA
ON THE
CHICAGO-BURLINGTON & QUINCY RY.

FIG. 2 A.

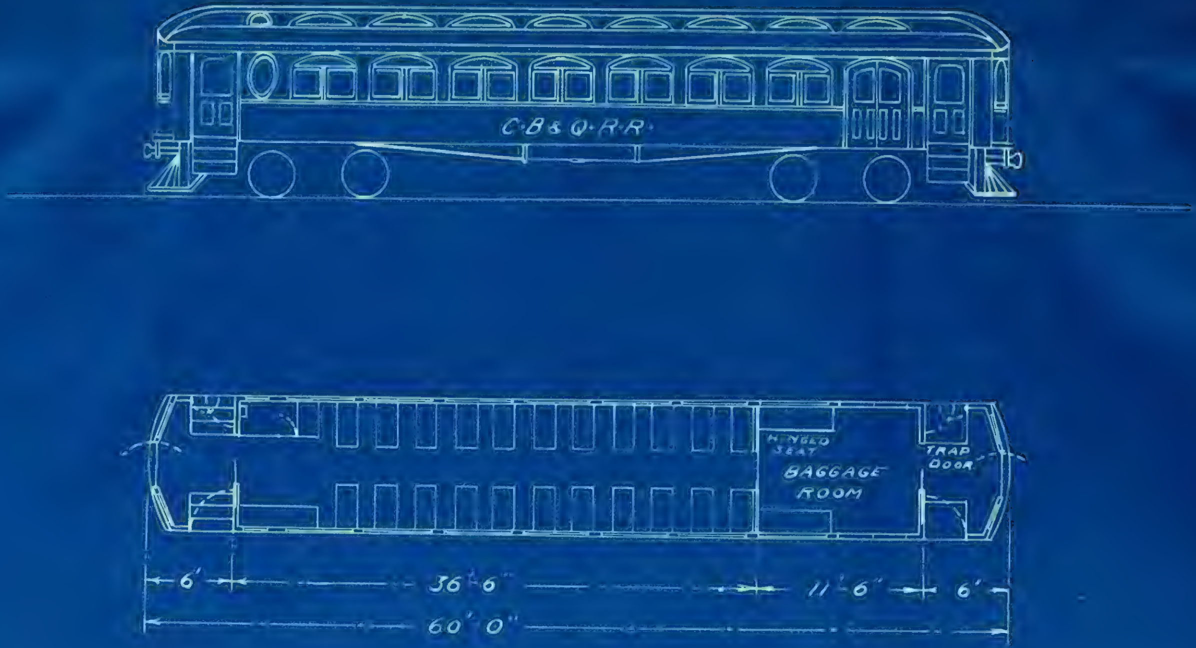
[illegible]
[illegible] OF [illegible]
[illegible]



C. B. & Q. R. R.
PROPOSED PASSENGER CAR
FOR
CHICAGO ELECTRIC ZONE

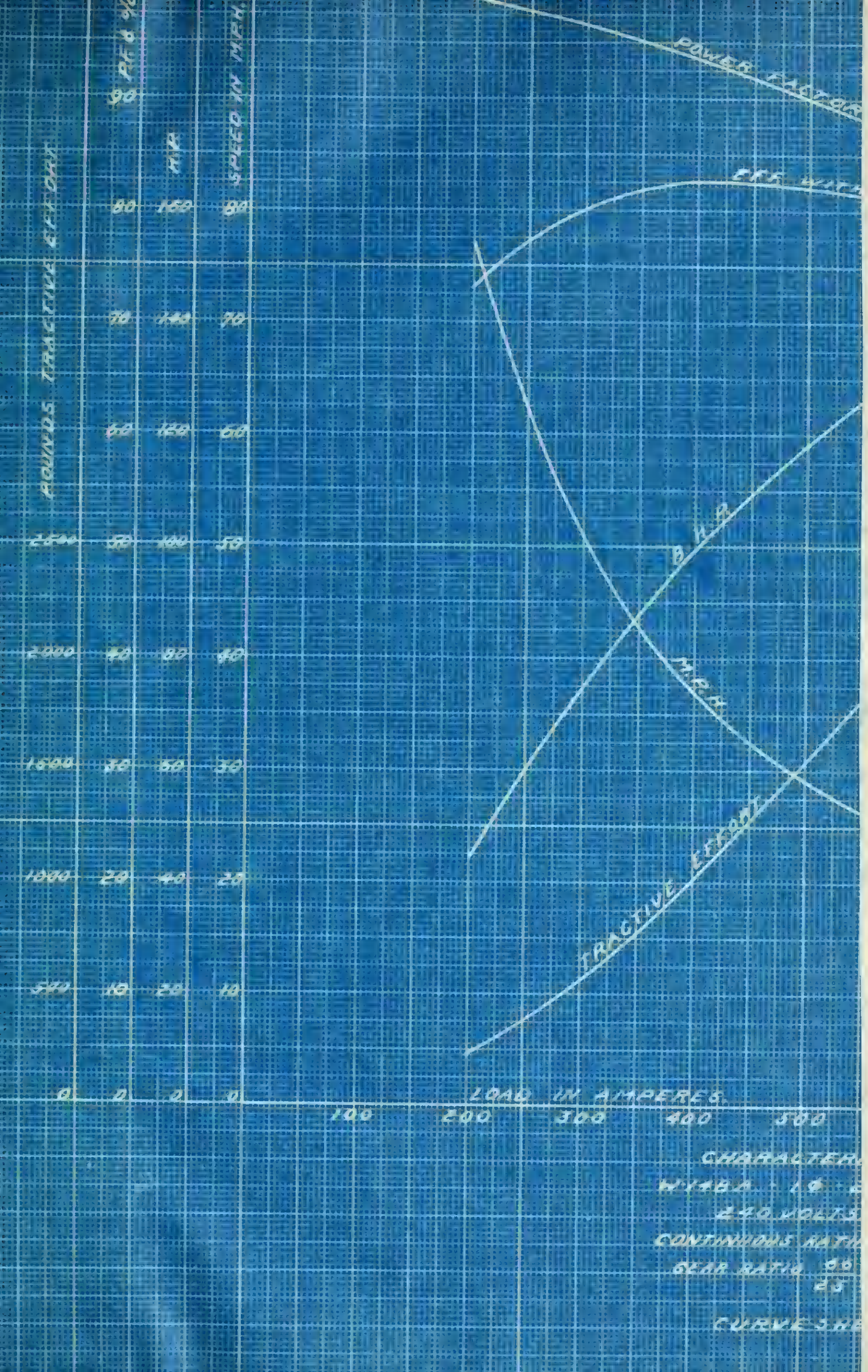
FIG. III

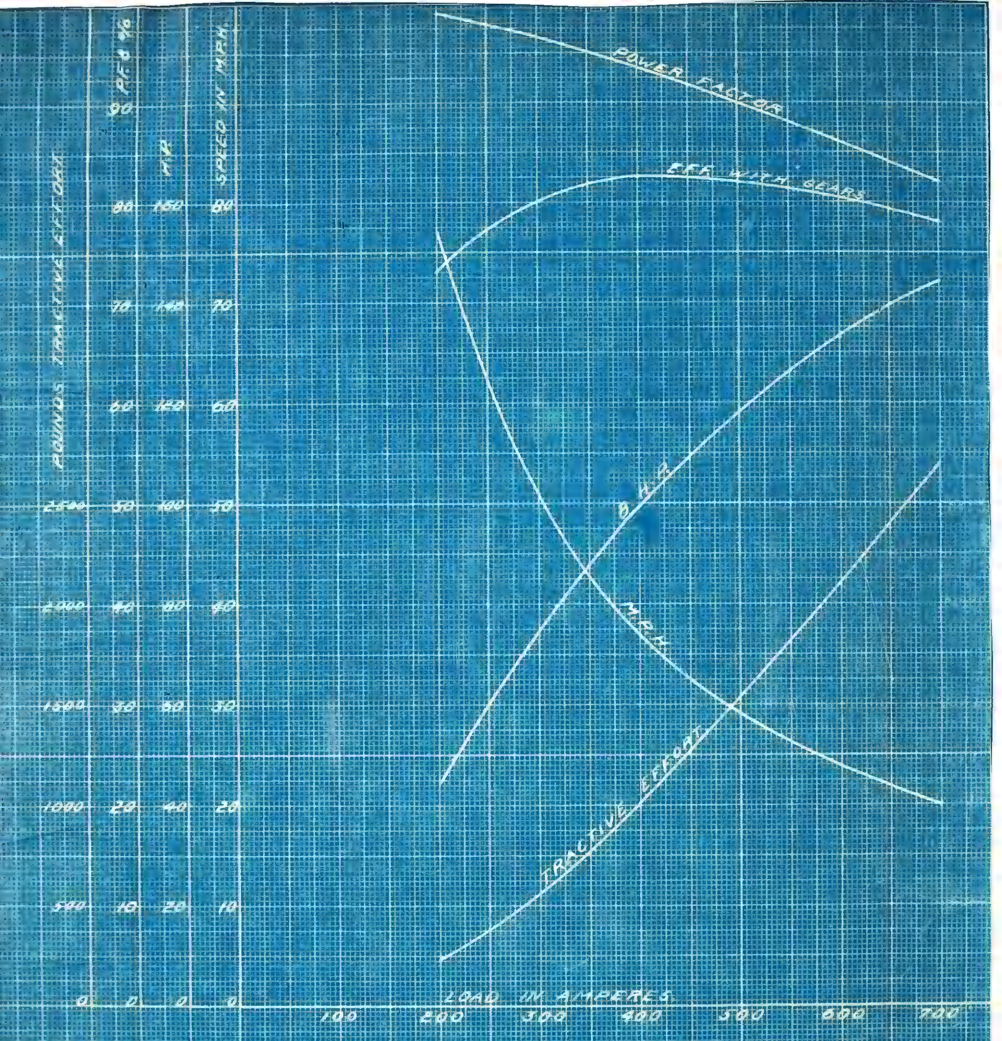
[illegible]
[illegible]
[illegible]



C. B. & Q. R. R.
PROPOSED COMBINATION CAR
FOR
CHICAGO ELECTRIC ZONE

FIG. IV


POUNDS TRACTIVE EFFORT
P.F. & %
H.P.
SPEED IN M.P.H.
90
80 160 80
70 140 70
60 120 60
2500 50 100 50
2000 40 80 40
1500 30 60 30
1000 20 40 20
500 10 20 10
0 0 0 0
POWER FACTOR
EFF. WIT
B.H.P.
M.P.H.
TRACTIVE EFFORT
LOAD IN AMPERES.
100 200 300 400 500
CHARACTER
W-148-A 1 6
240 VOLTS
CONTINUOUS RAT
GEAR RATIO 60
25
CURVE SHE



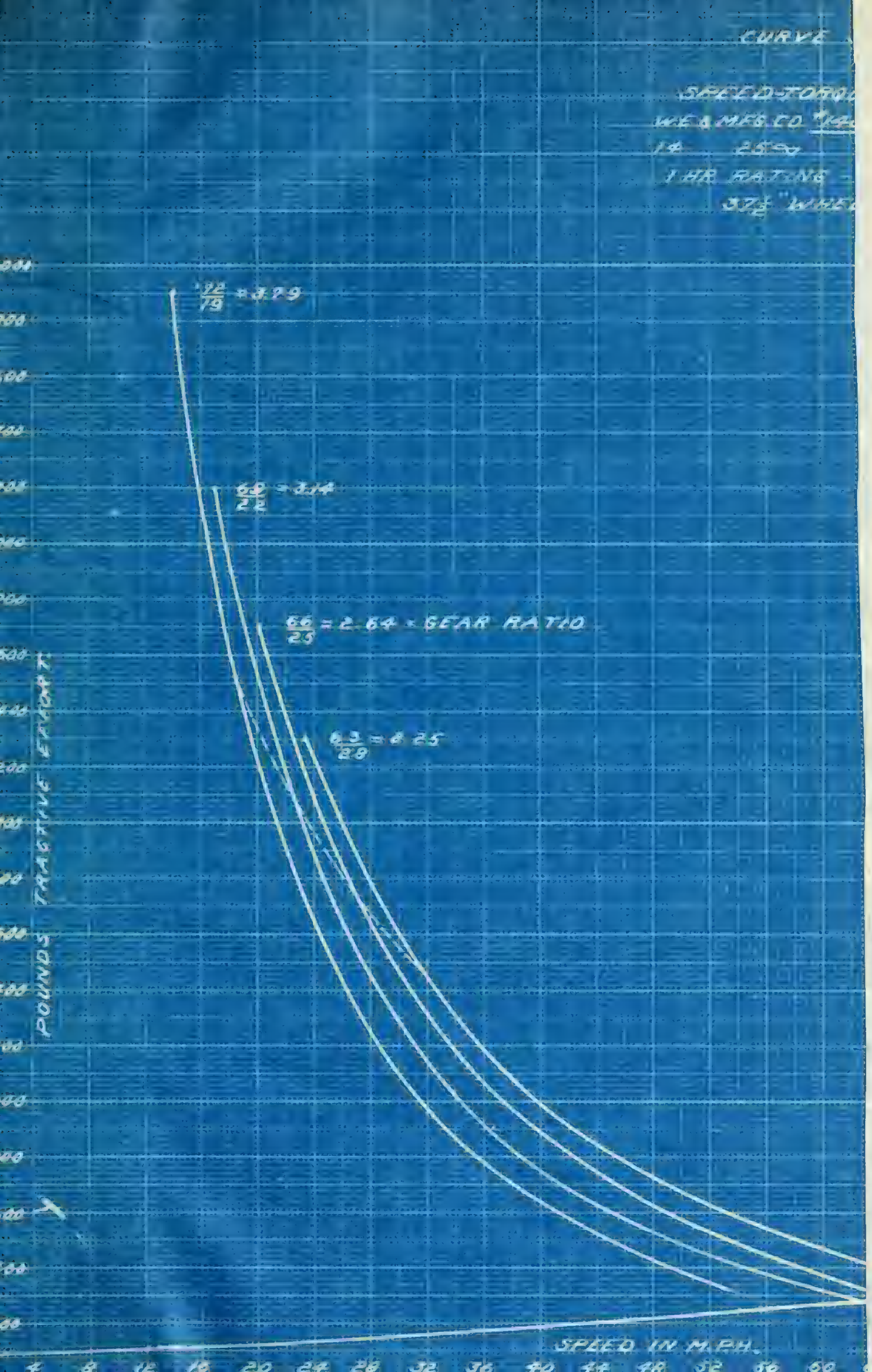
CHARACTERISTICS
W.I.A.B.A 1Φ 25~ RY MOTOR
240 VOLTS 540 AMP
CONTINUOUS RATING 240V-295AMP
GEAR RATIO $\frac{58}{20}$ WHEELS 33½

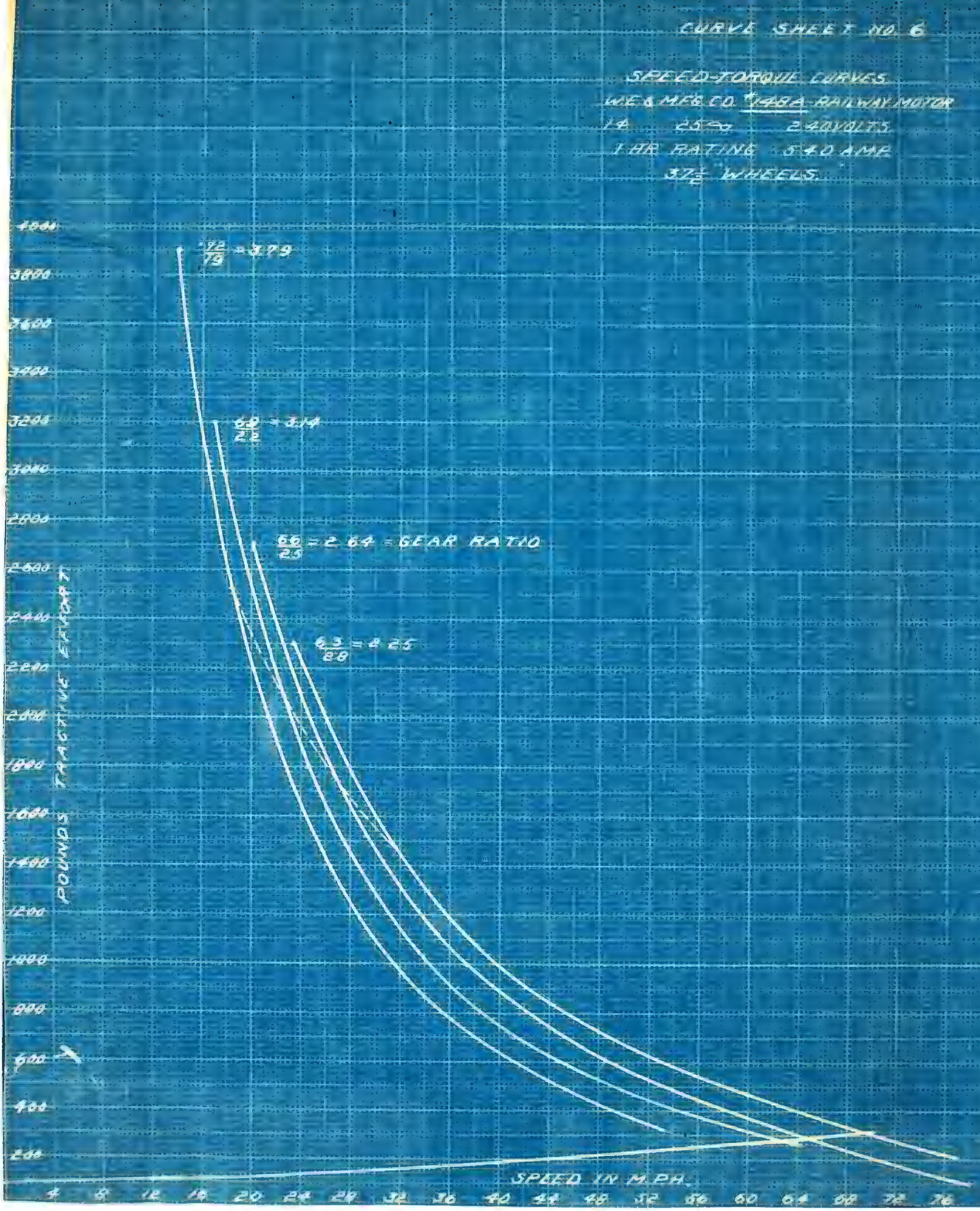
CURVE SHEET # V

ARTHUR

[illegible]

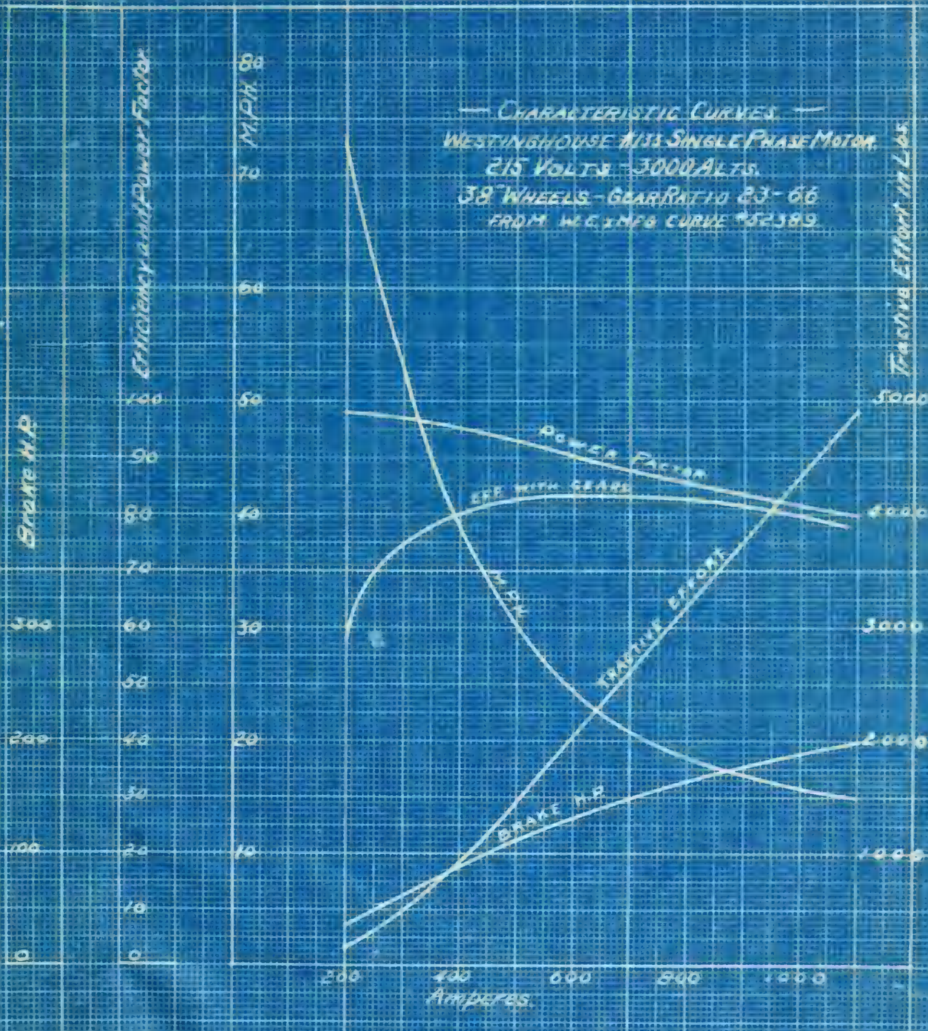
[illegible]


CURVE
SPEED-TORQU
W.E.& MFG.CO. #14
14 25~
1 HR RATING -
37½" WHE
62/19 = 3.29
69/22 = 3.14
66/25 = 2.64 = GEAR RATIO
63/28 = 2.25
POUNDS TRACTIVE EFFORT.
SPEED IN M.P.H.
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60



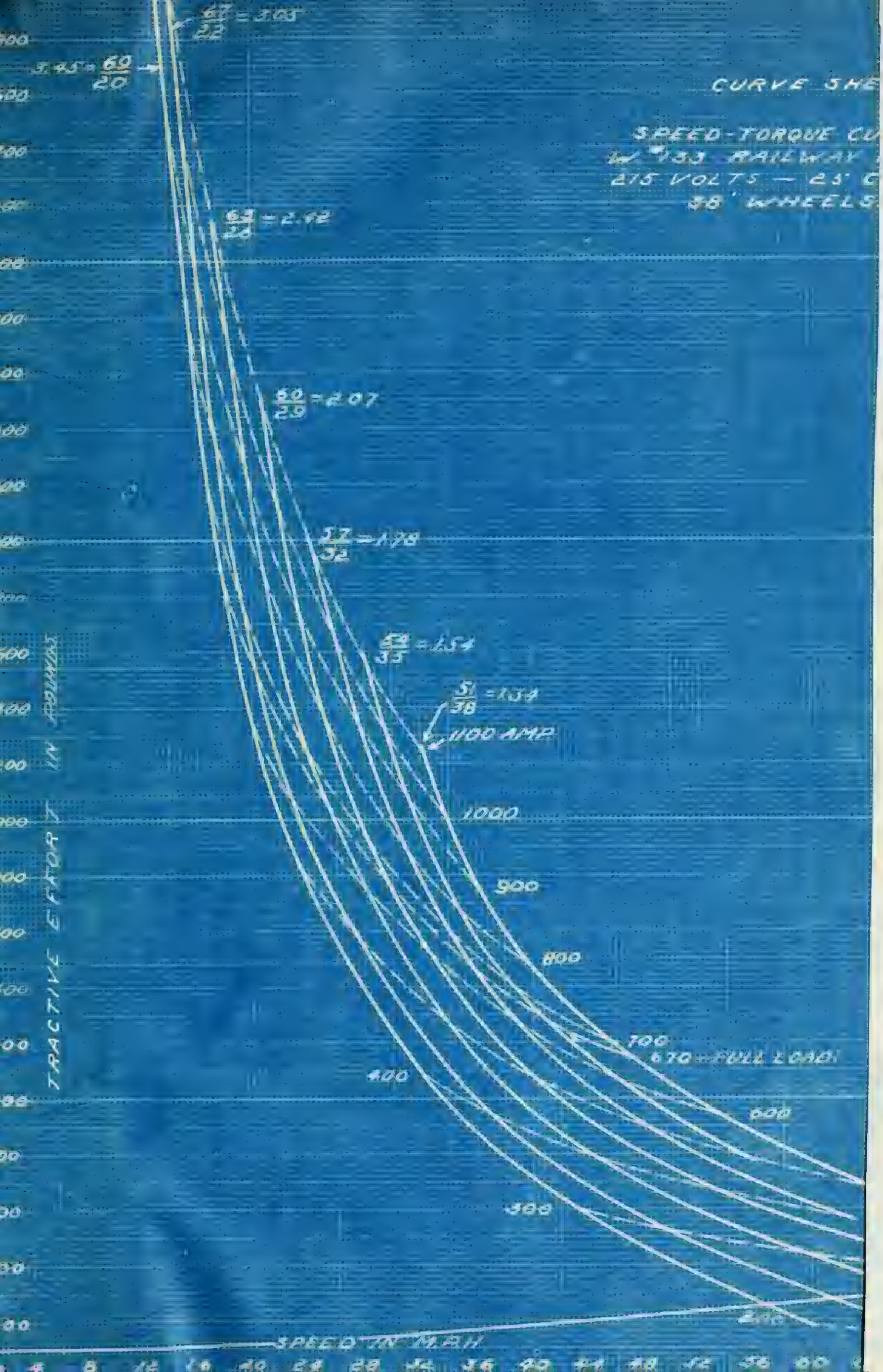
CURVE SHEET NO. 6

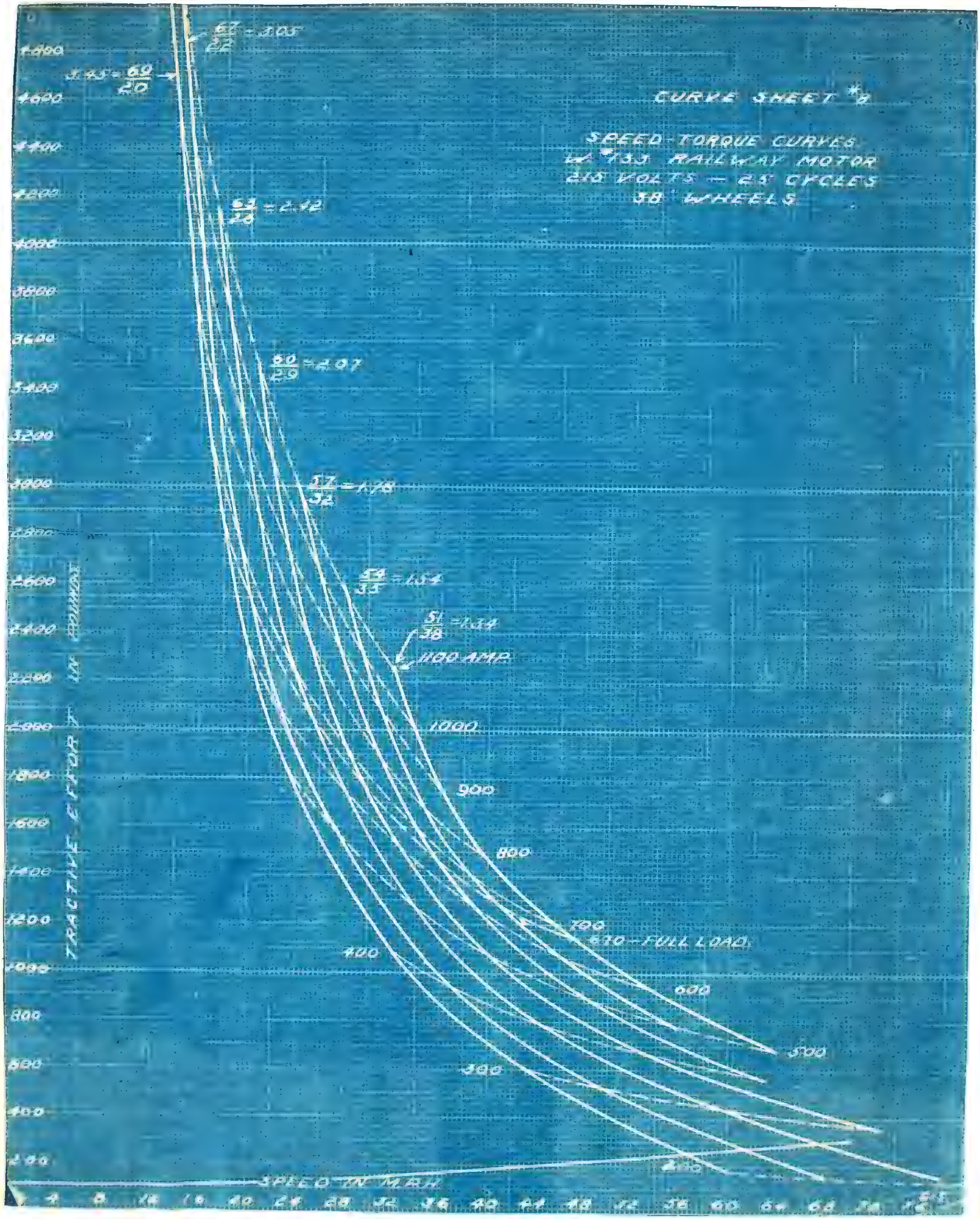
SPEED-TORQUE CURVES.
W.E.& MFG. CO. #148-A RAILWAY MOTOR
1Φ 25~ 240 VOLTS.
1 HR. RATING 540 AMP.
37½" WHEELS.

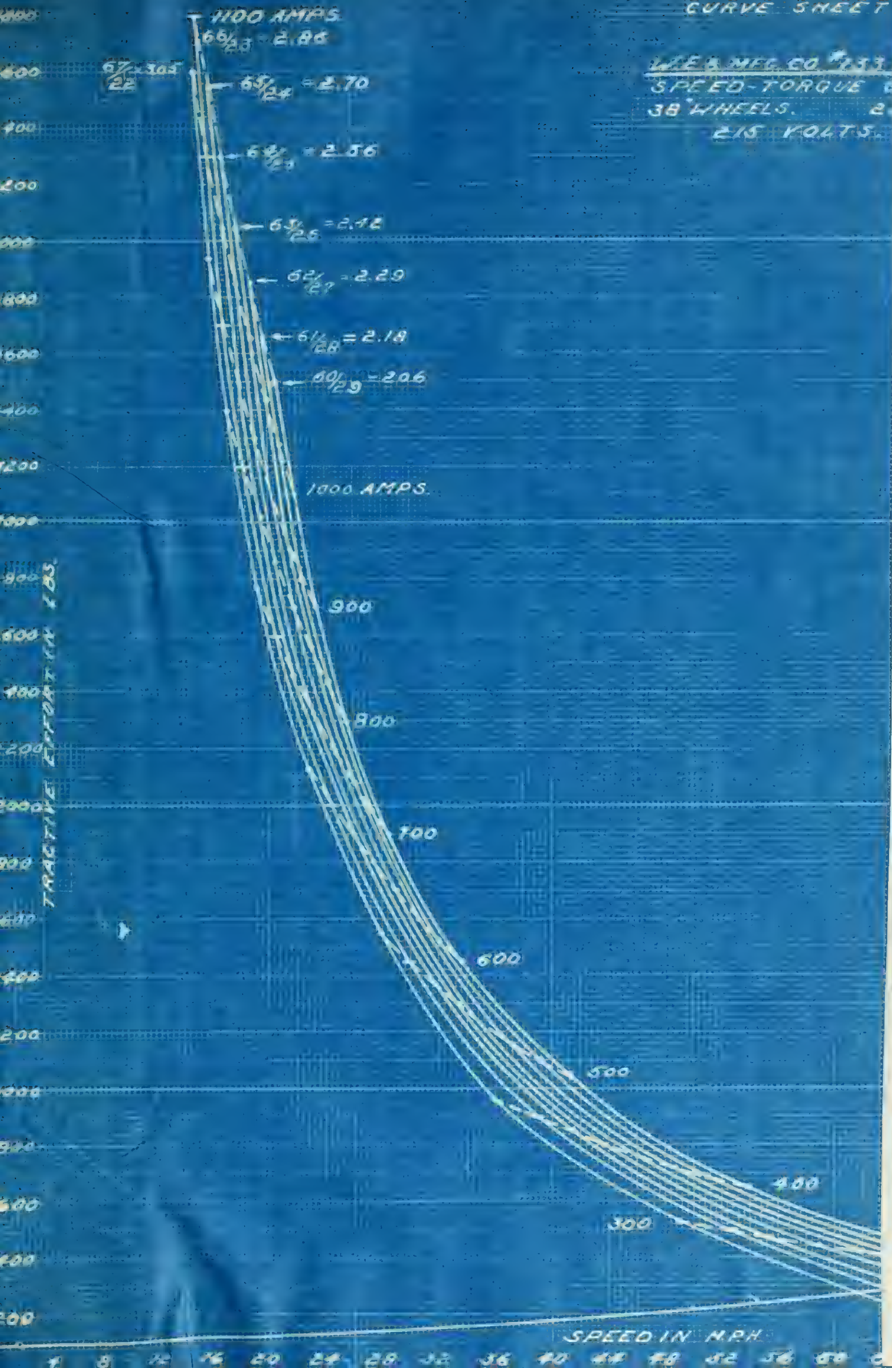


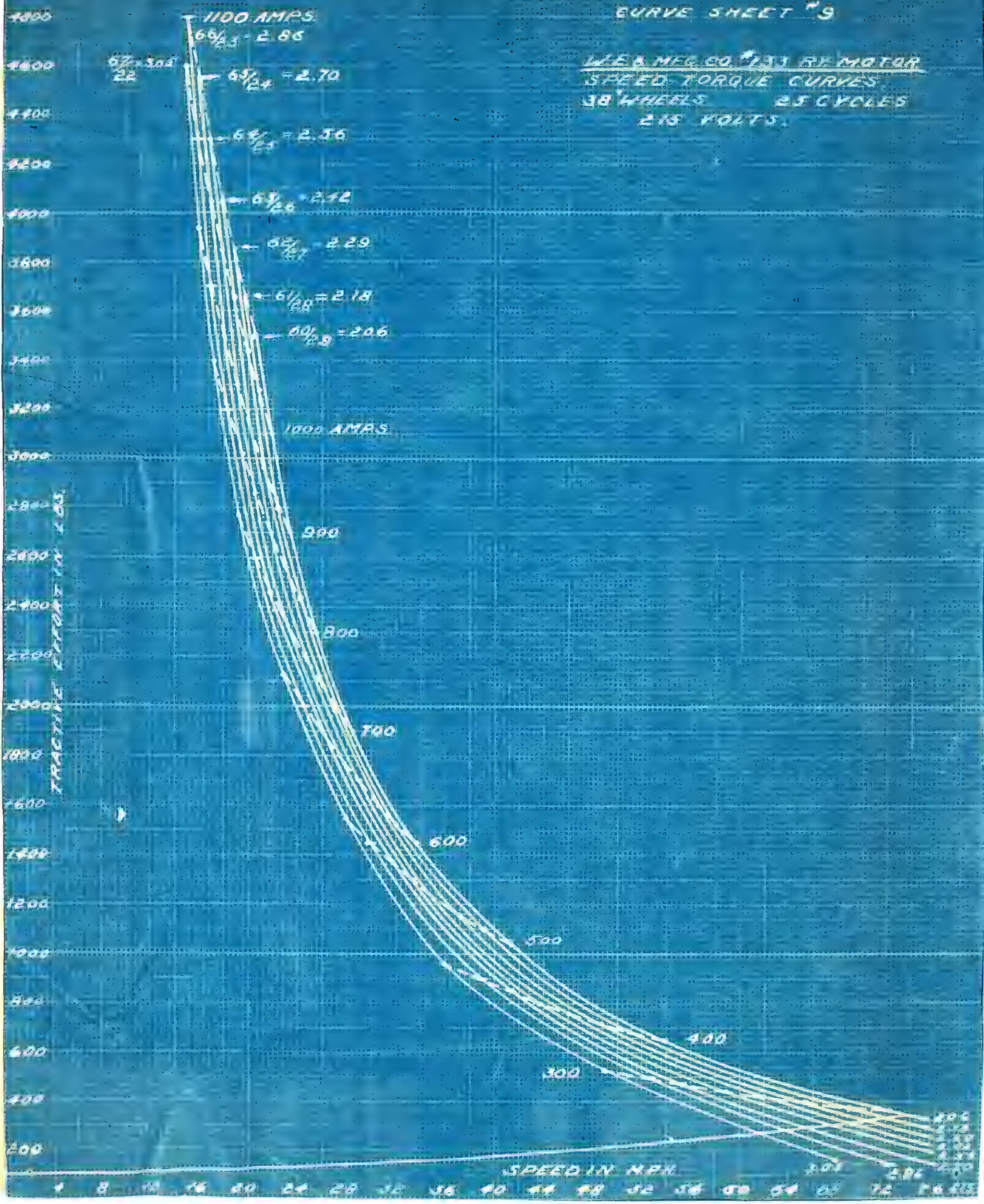
— CHARACTERISTIC CURVES —
WESTINGHOUSE #135 SINGLE PHASE MOTOR
215 VOLTS – 3000 ALTS.
38" WHEELS – GEAR RATIO 23 – 66
FROM W.E.& MFG CURVE #52389

CURVE SHEET #7

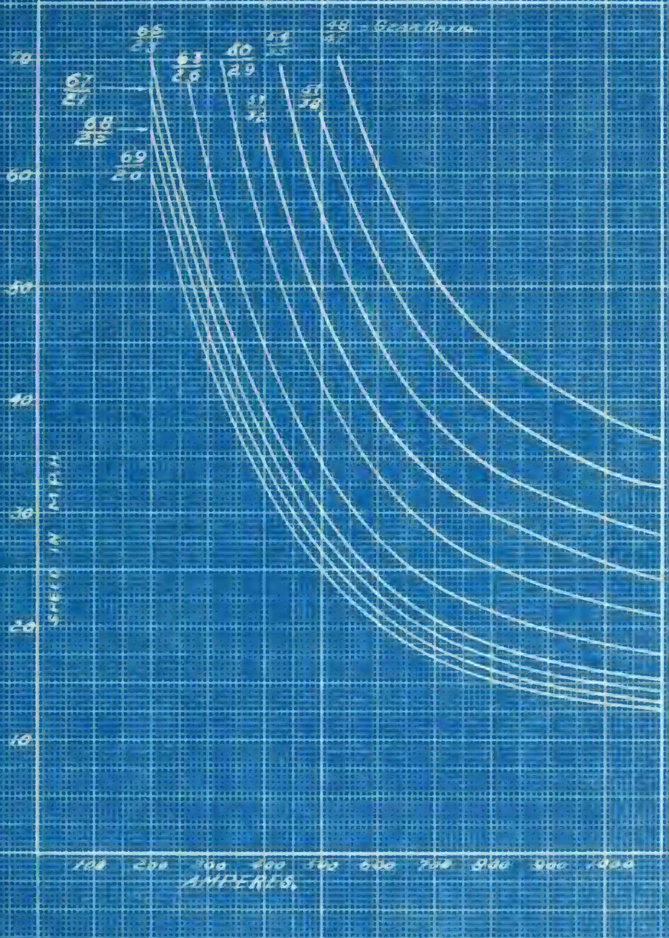

CURVE SHE
SPEED-TORQUE CU
W #133 RAILWAY
275 VOLTS — 25 C
38" WHEELS
67/22 = 3.05
3.45 = 69/20
63/26 = 2.42
60/29 = 2.07
57/32 = 1.78
54/35 = 1.54
51/38 = 1.34
1100 AMP.
1000
900
800
700
670 – FULL LOAD.
600
400
300
200
TRACTIVE EFFORT IN POUNDS
SPEED IN M.P.H.
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60


CURVE SHEET #8
SPEED-TORQUE CURVES
W. 133 RAILWAY MOTOR
218 VOLTS — 25 CYCLES
38" WHEELS
67/22 = 3.05
3.45 = 69/20
63/26 = 2.42
60/29 = 2.07
57/32 = 1.78
54/35 = 1.54
51/38 = 1.34
1100 AMP.
1000
900
800
700
610 — FULL LOAD
600
500
400
300
200
TRACTIVE EFFORT IN POUNDS
SPEED IN M.P.H.
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76

CURVE SHEET
W.E.& MFG. CO. #233
SPEED-TORQUE C
38" WHEELS. 2
215 VOLTS.
1100 AMPS.
66/23 = 2.86
67/22 = 3.05
65/24 = 2.70
64/25 = 2.56
63/26 = 2.42
62/27 = 2.29
61/28 = 2.18
60/29 = 2.06
1000 AMPS.
900
800
700
600
500
400
300
TRACTIVE EFFORT IN LBS.
SPEED IN M.P.H.
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60

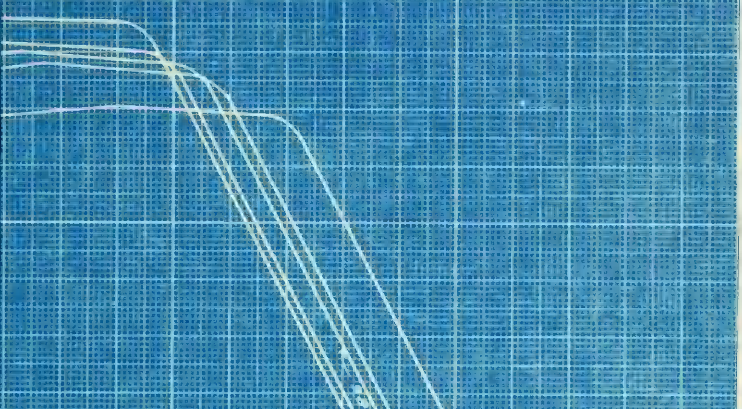

CURVE SHEET #9
W.E.& MFG. CO. #133 R.R. MOTOR
SPEED TORQUE CURVES.
38" WHEELS 25 CYCLES
213 VOLTS.
1100 AMPS.
66/23 = 2.86
67/22 = 3.05
65/24 = 2.70
64/25 = 2.56
63/26 = 2.42
62/27 = 2.29
61/28 = 2.18
60/29 = 2.06
1000 AMPS.
900
800
700
600
500
400
300
3.05
2.06
TRACTIVE EFFORT IN LBS
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
SPEED IN MPH.
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76

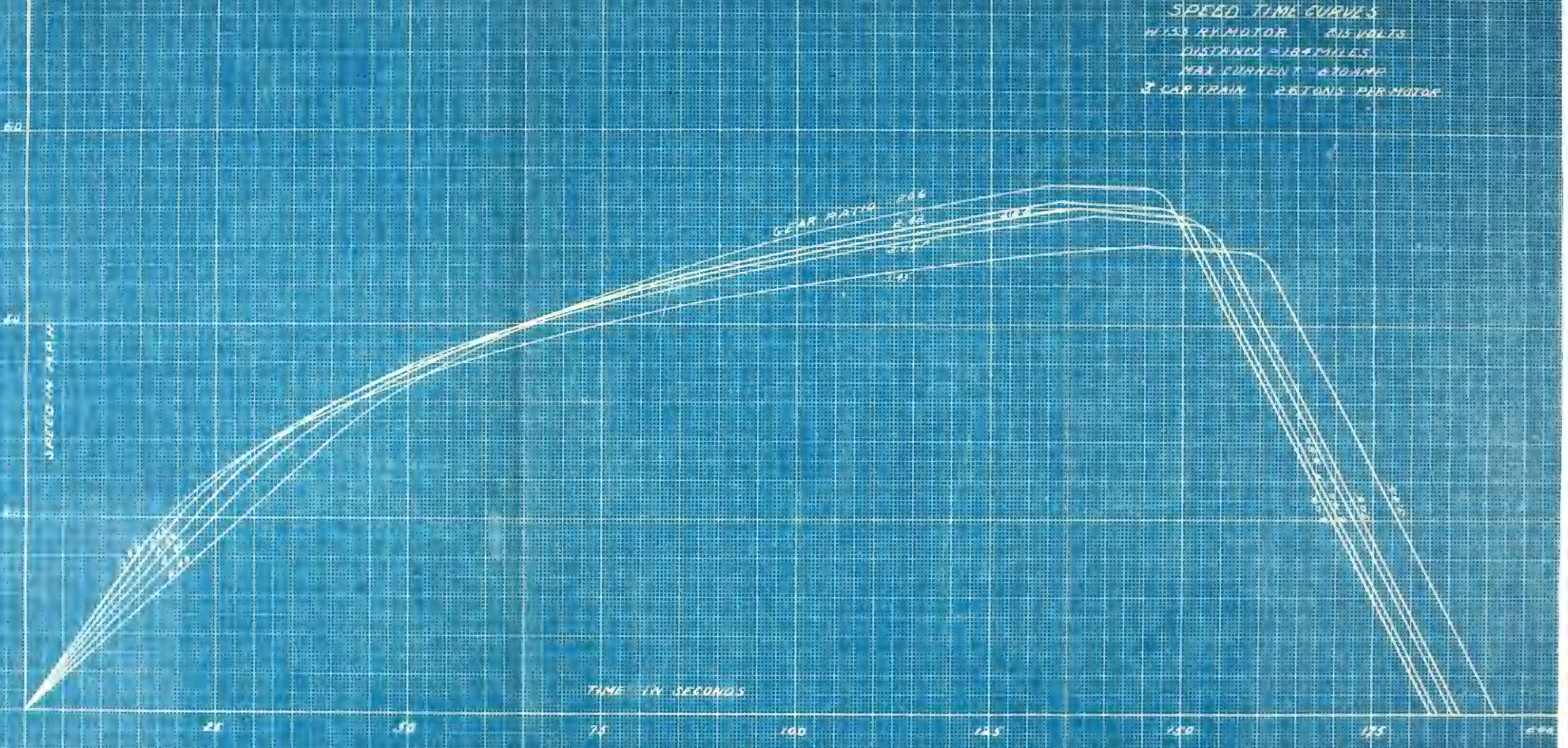
SPEED CHARACTERISTIC
W.E.&M.Co. #133 70-RY MOTOR
670 AMPS. 250 VOLTS.



CURVE SHEET # 10

SPEED TIME CURVES
W.133 RY. MOTOR 615 VOLTS
DISTANCE = 1.84 MILES
MAX CURRENT = 670 AMP.
3 CAR TRAIN 26 TONS PER MOTOR





CURVE SHEET #11

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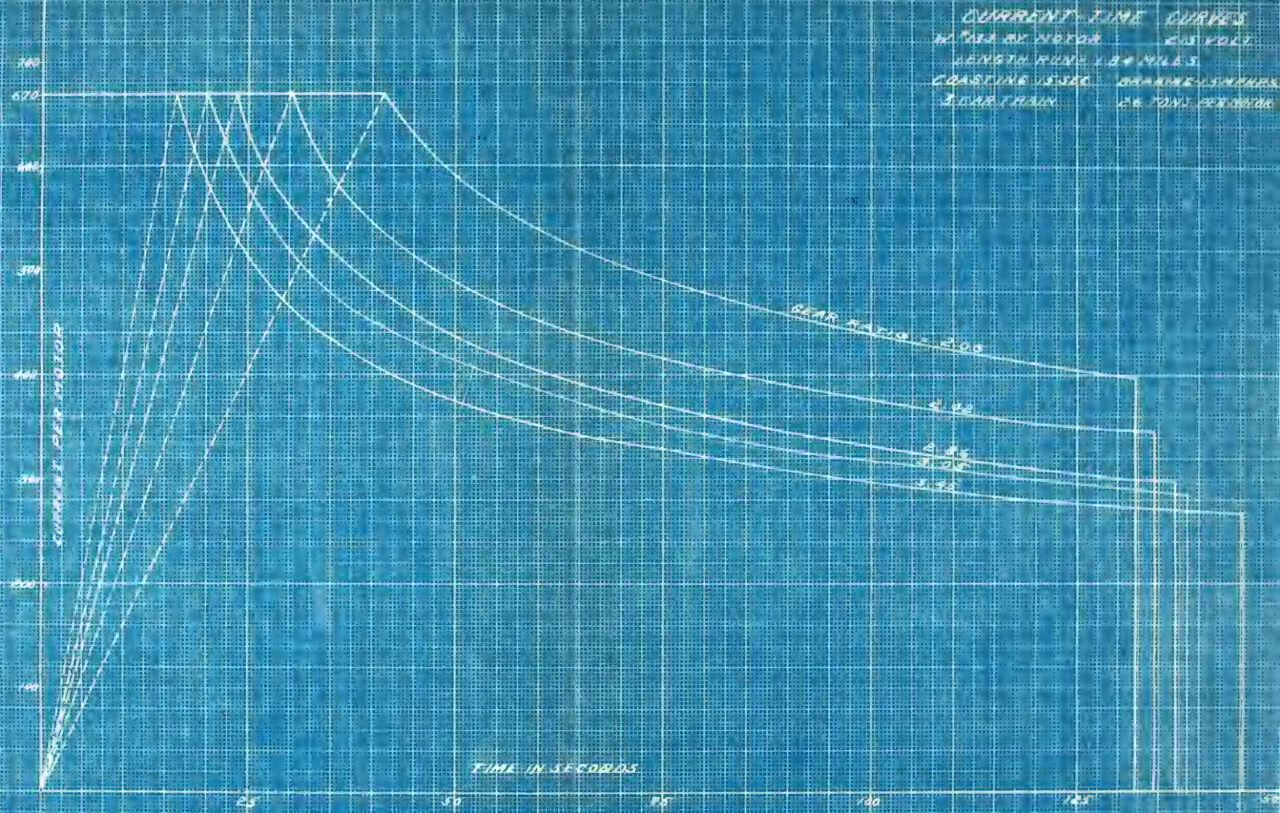
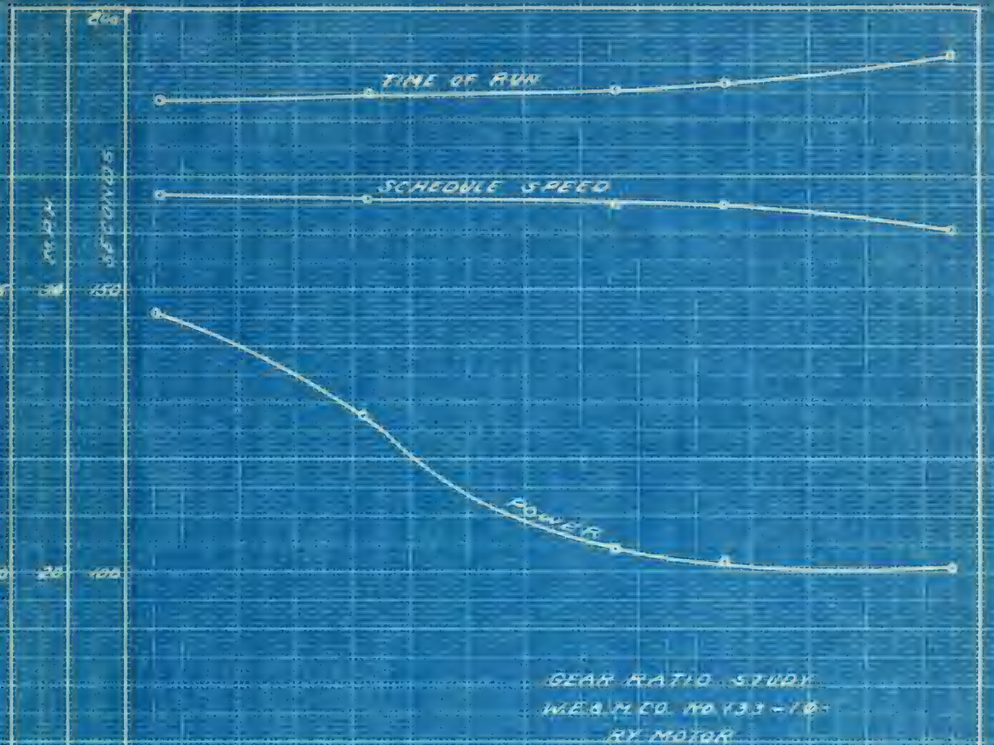


CURVE SHEET #12



GEAR RATIO STUDY
W.E.&M.CO. NO.133-10-
RY. MOTOR
3-56 TON CARS PER TRAIN.

CURVE SHEET #13

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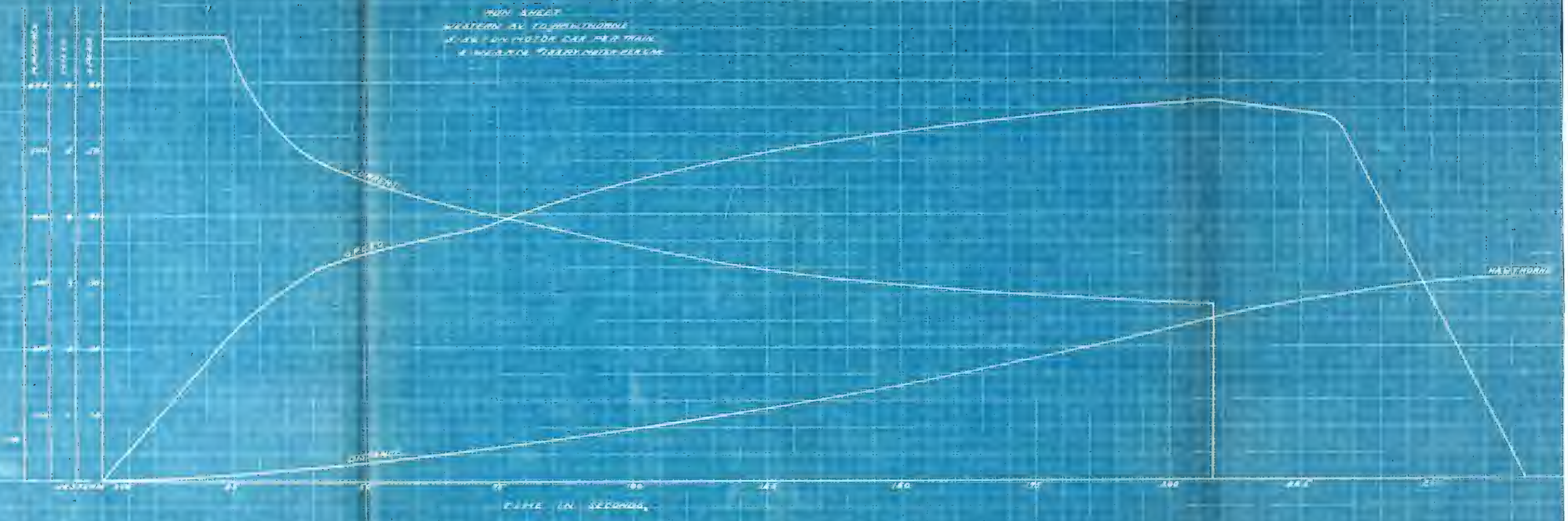
14



CURVE SHEET # 18

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INSTITUTE OF TECHNOLOGY

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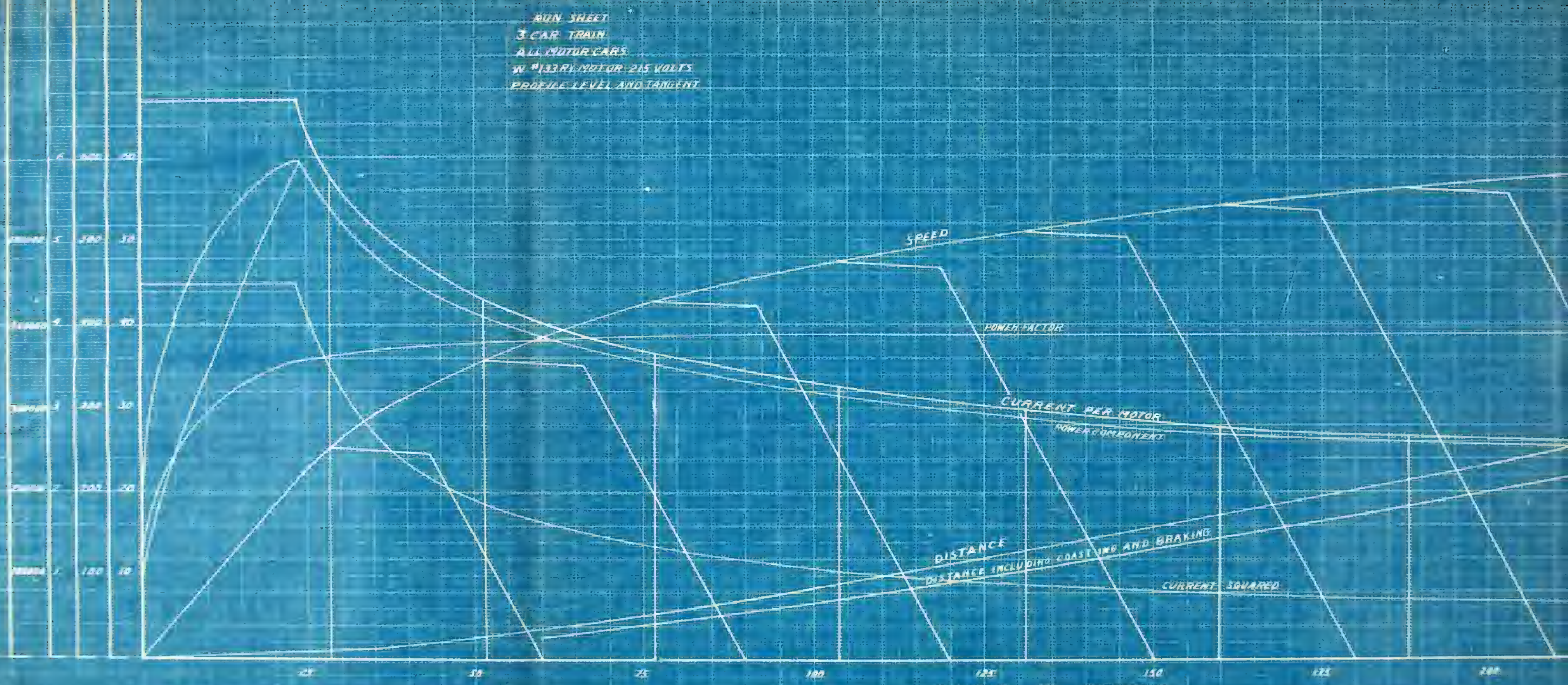
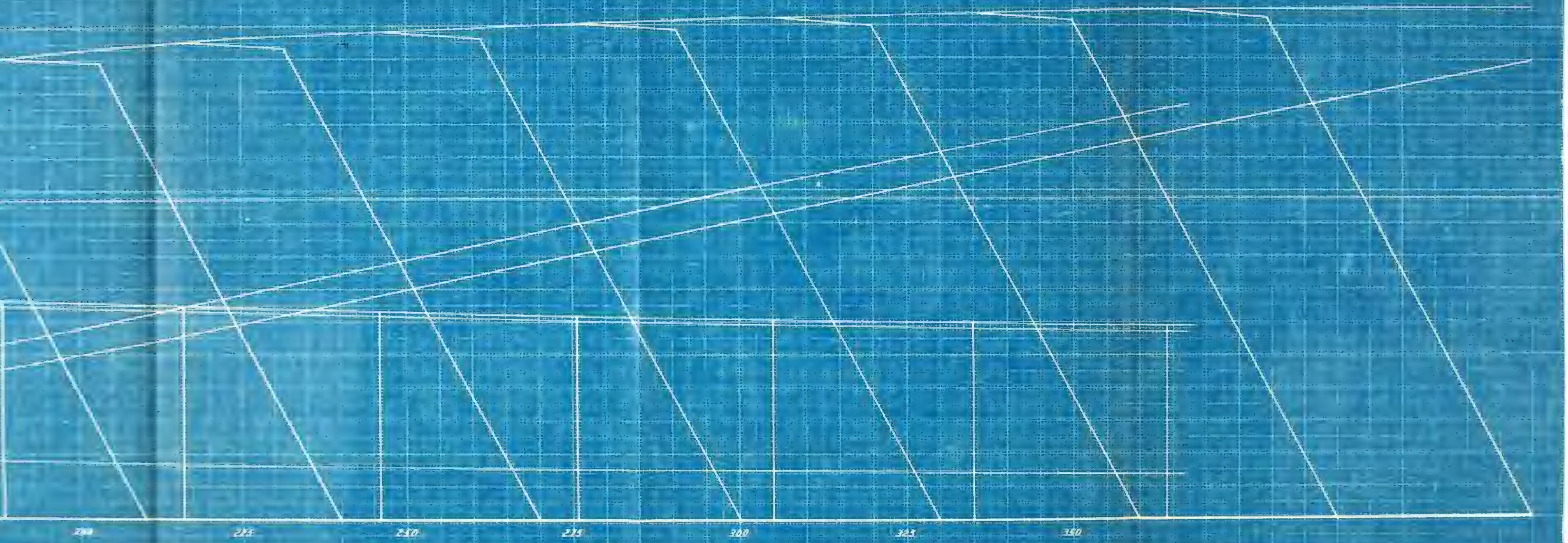
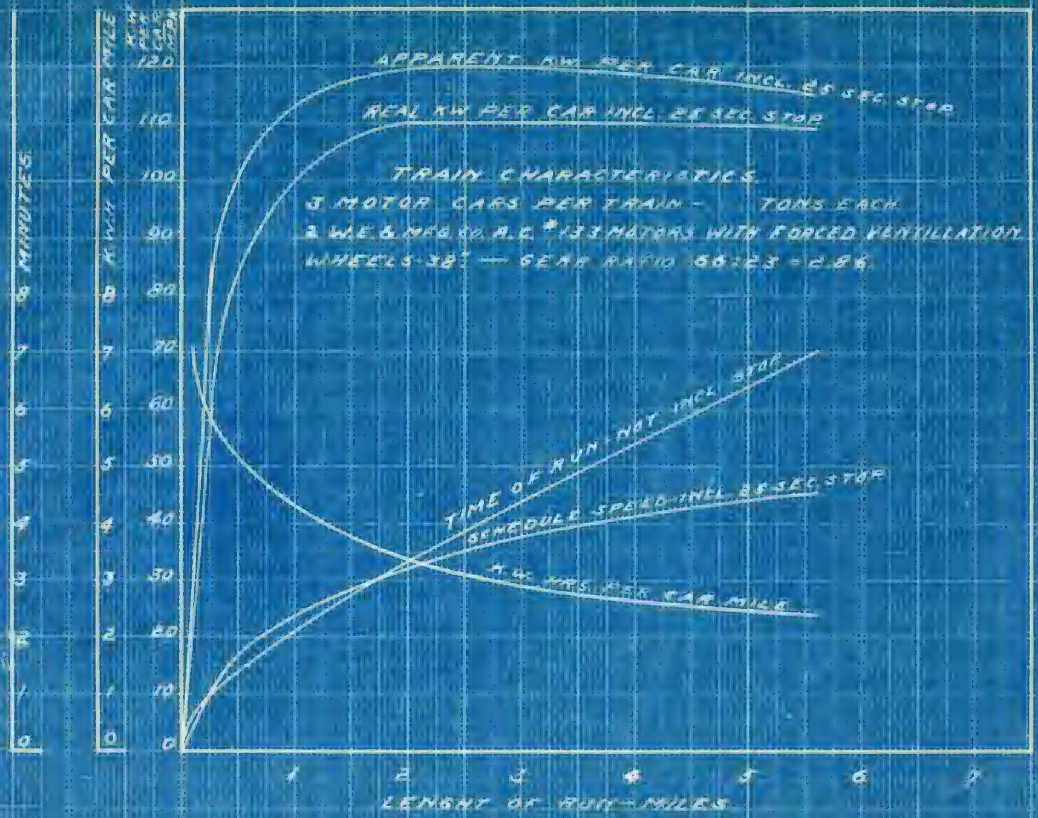


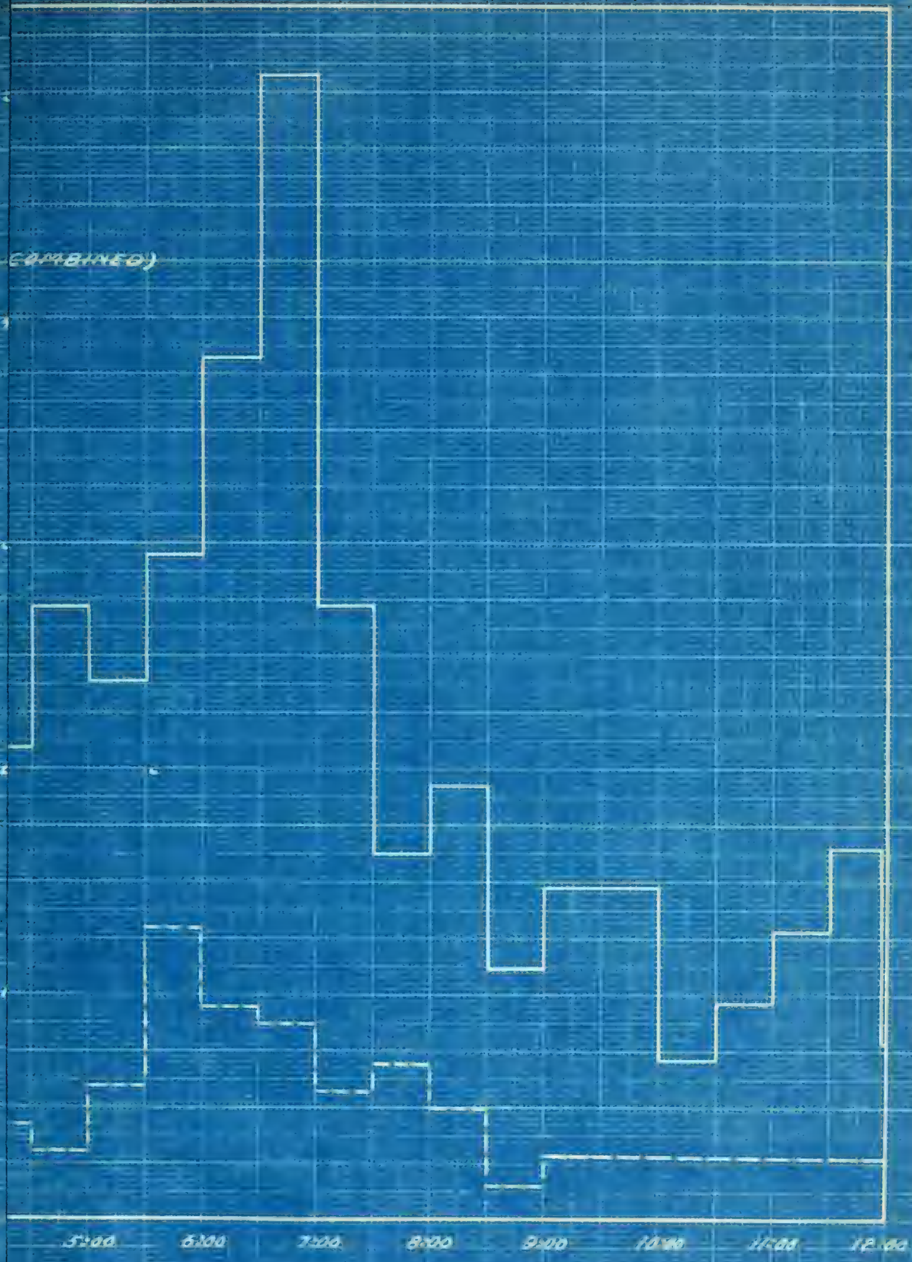
CURVE SHEET #25


200
225
250
275
300
325
350

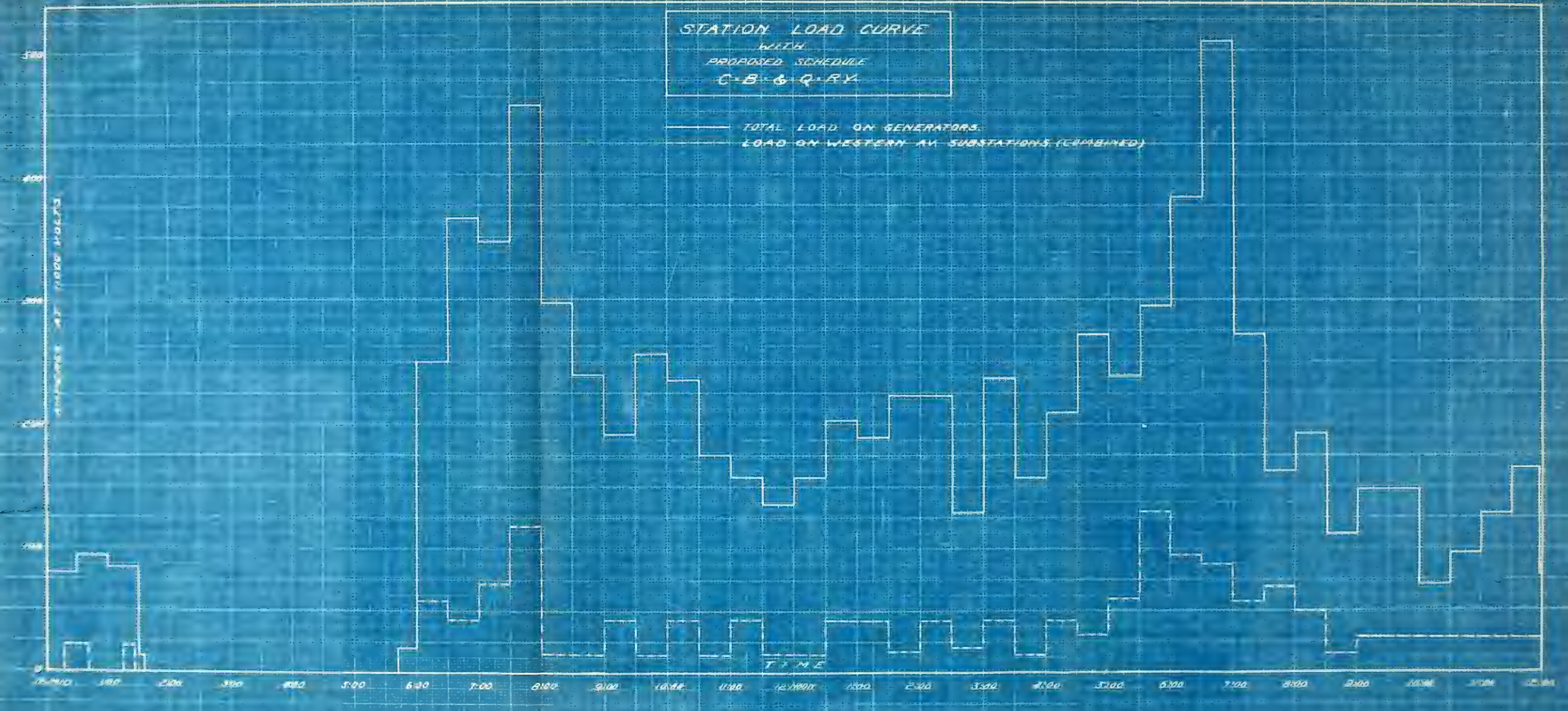
ACQUIRED
DEPARTMENT OF ENTOMOLOGY
[illegible]



CURVE SHEET #16


COMBINED)
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00

[illegible]
[illegible]
[illegible]



STATION LOAD CURVE
WITH
PROPOSED SCHEDULE
C·B·&·Q·RY.

CURVE SHEET # 17

[illegible]
[illegible]
[illegible]

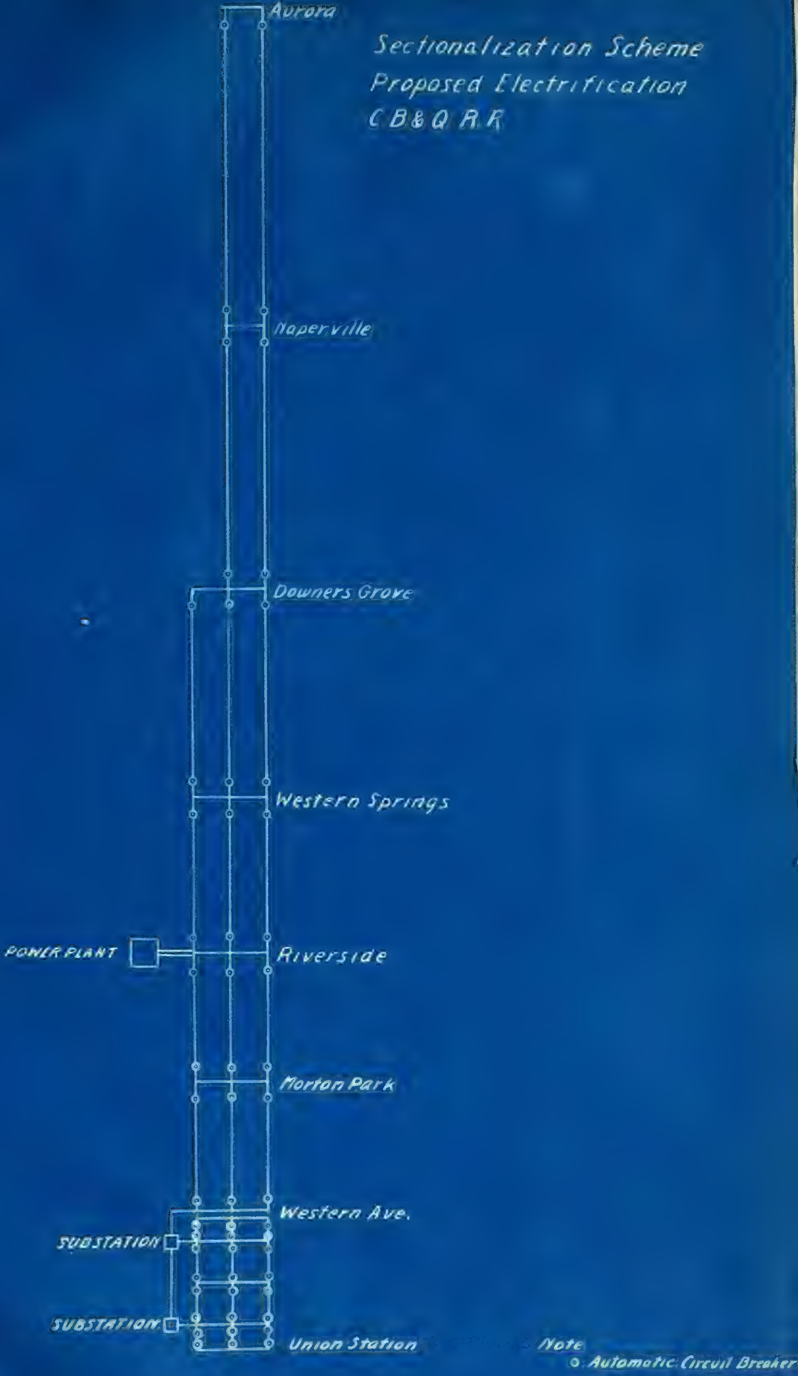

Sectionalization Scheme
Proposed Electrification
C.B.&Q. R.R.
Aurora
Naperville
Downers Grove
Western Springs
POWER PLANT
Riverside
Morton Park
Western Ave.
SUBSTATION
SUBSTATION
Union Station
Note
o. Automatic Circuit Breaker

FIG. 17 A.

ARCHIVES
[illegible]
[illegible]

Typical Two Track Bridge

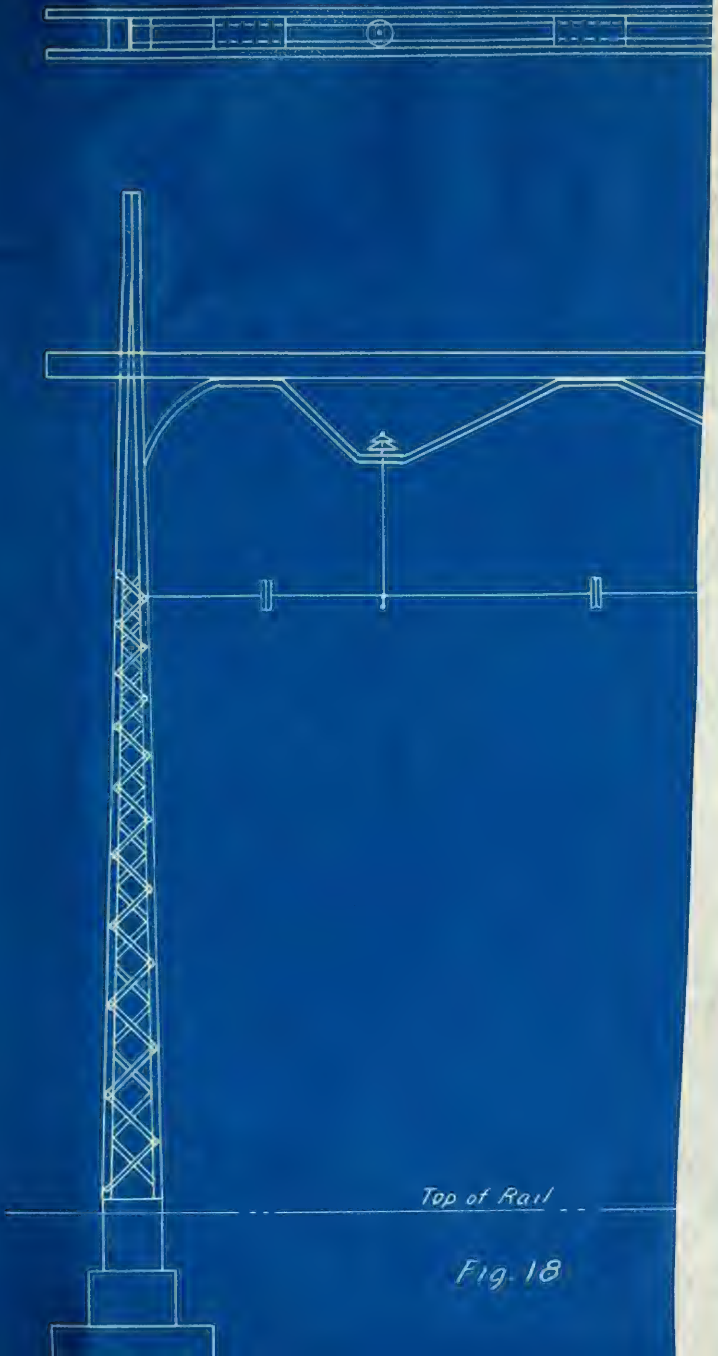


Fig. 18

[illegible]
[illegible]
[illegible]

Typical Two Track Bridge Scale $\frac{1}{4}'' = 1'$

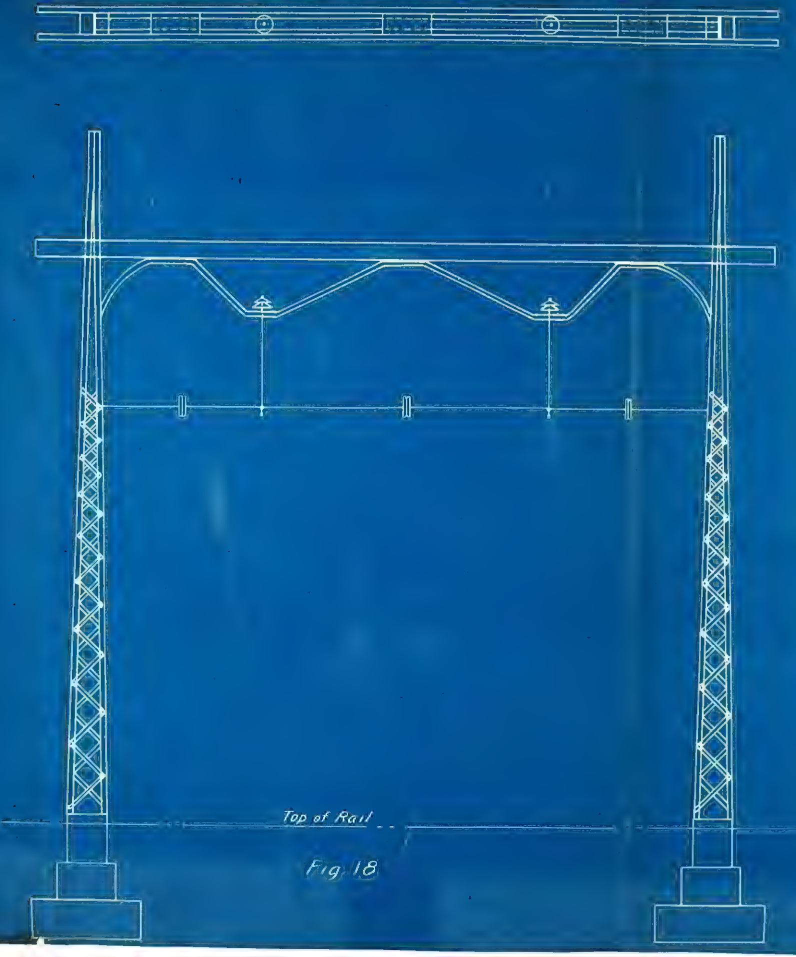
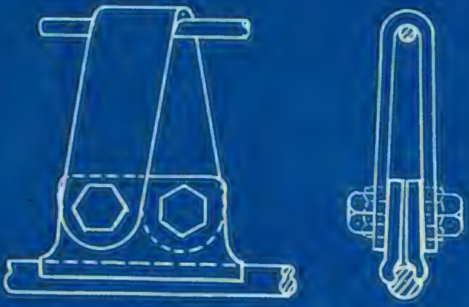


Fig. 18

[illegible]
[illegible]
[illegible]



C·B·& Q·R·R·
HANGER
FOR
SECONDARY TROLLEY

FIG. No 19

ARMOUR
INSTITUTE OF TECHNOLOGY
[illegible]

20

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

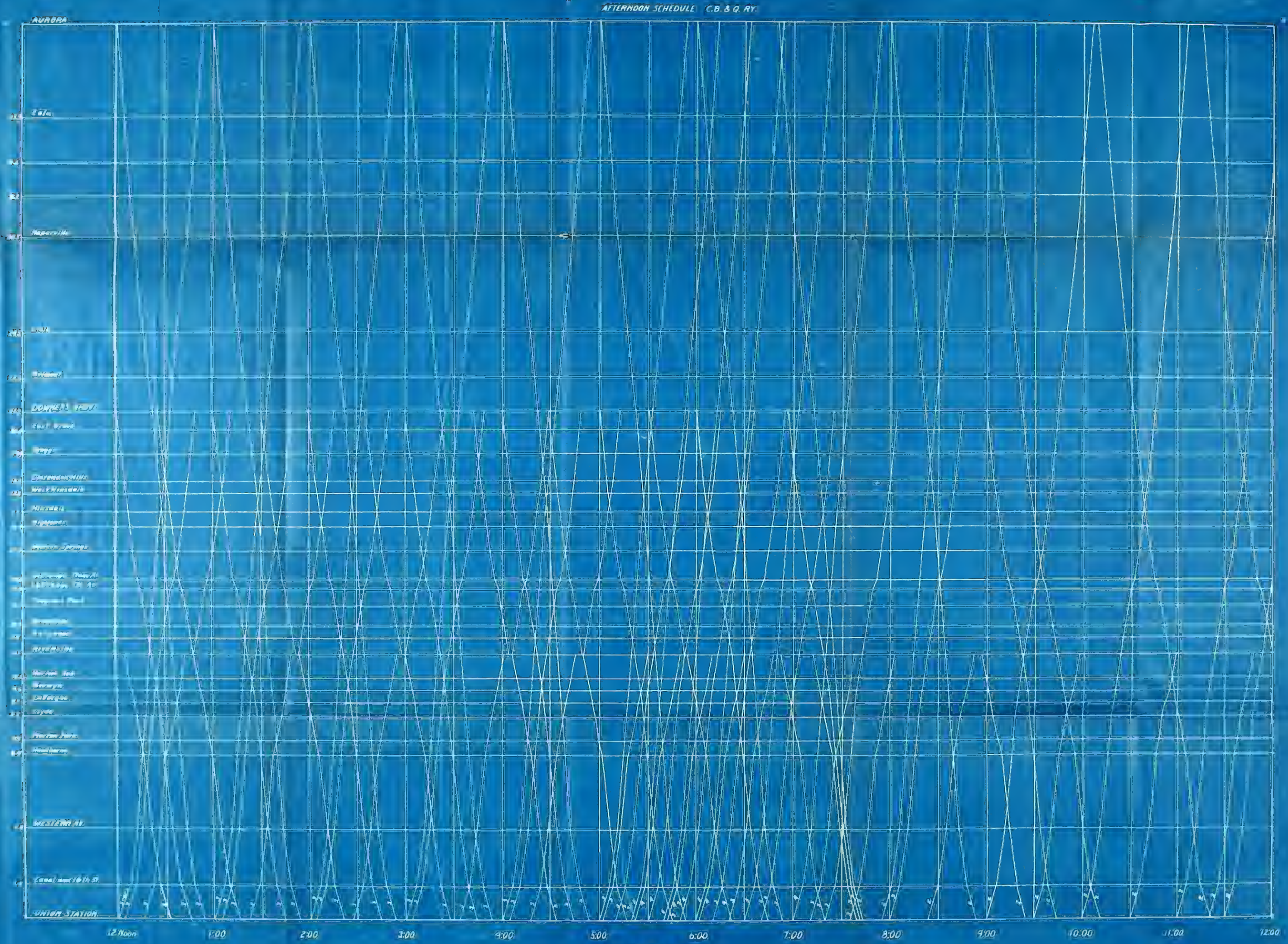

AFTERNOON SCHEDULE C.B. & Q. RY.
AURORA
Eola
Naperville
Lisle
Belmont
DOWNERS GROVE
Clarendon Hills
West Hinsdale
Hinsdale
Highlands
Western Springs
Riverside
Harlem Ave.
Berwyn
LaVergne
Clyde
Morton Park
Hawthorne
WESTERN AV.
Canal and 16th St.
UNION STATION
12 Noon
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00

FIG. 20

ARMOUR
INSTITUTE OF TECHNOLOGY
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21

MORNING SCHEDULE C·B·&·Q·RY·

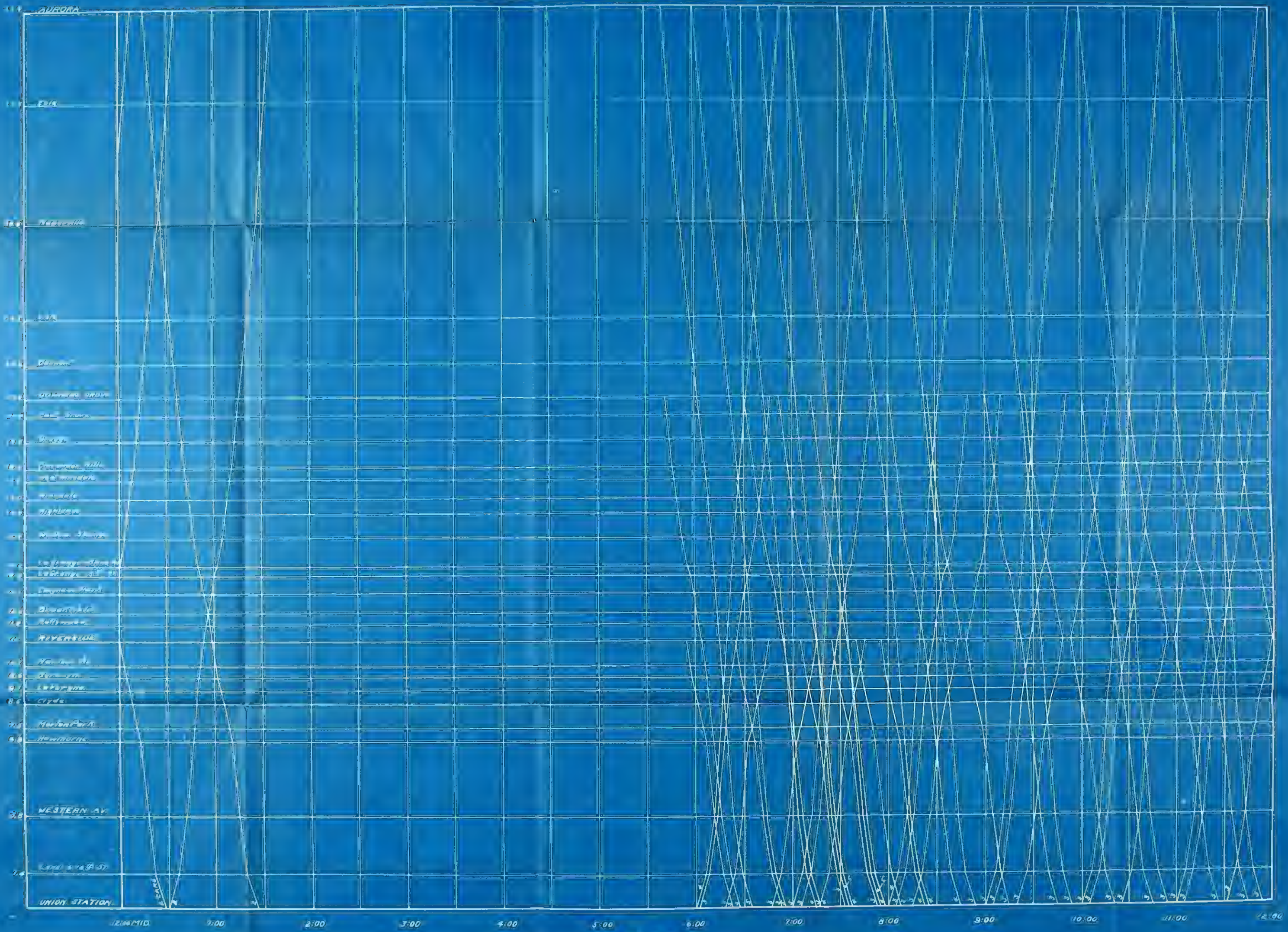

FIG. 21

ARMOUR
[illegible]
[illegible]

22

ARMOUR
[illegible]
[illegible]

Proposed Substation
for
C.B.&Q. RY.

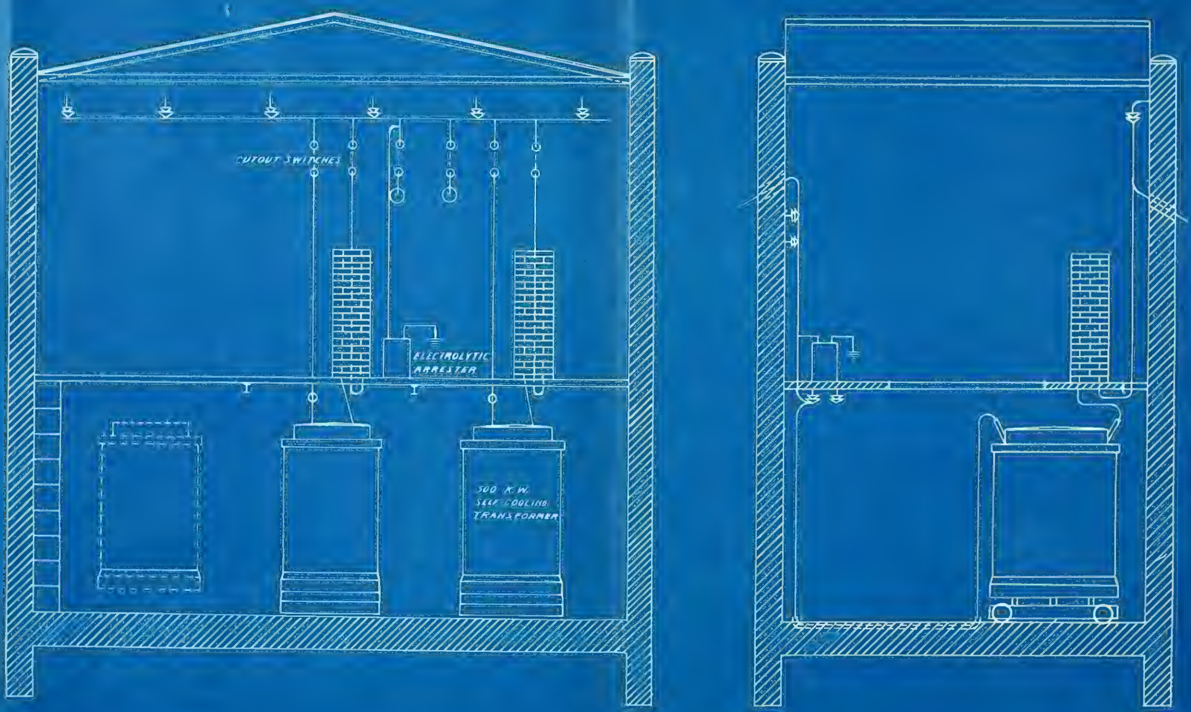

FIG. 22

[illegible]
[illegible] OF [illegible]
[illegible]

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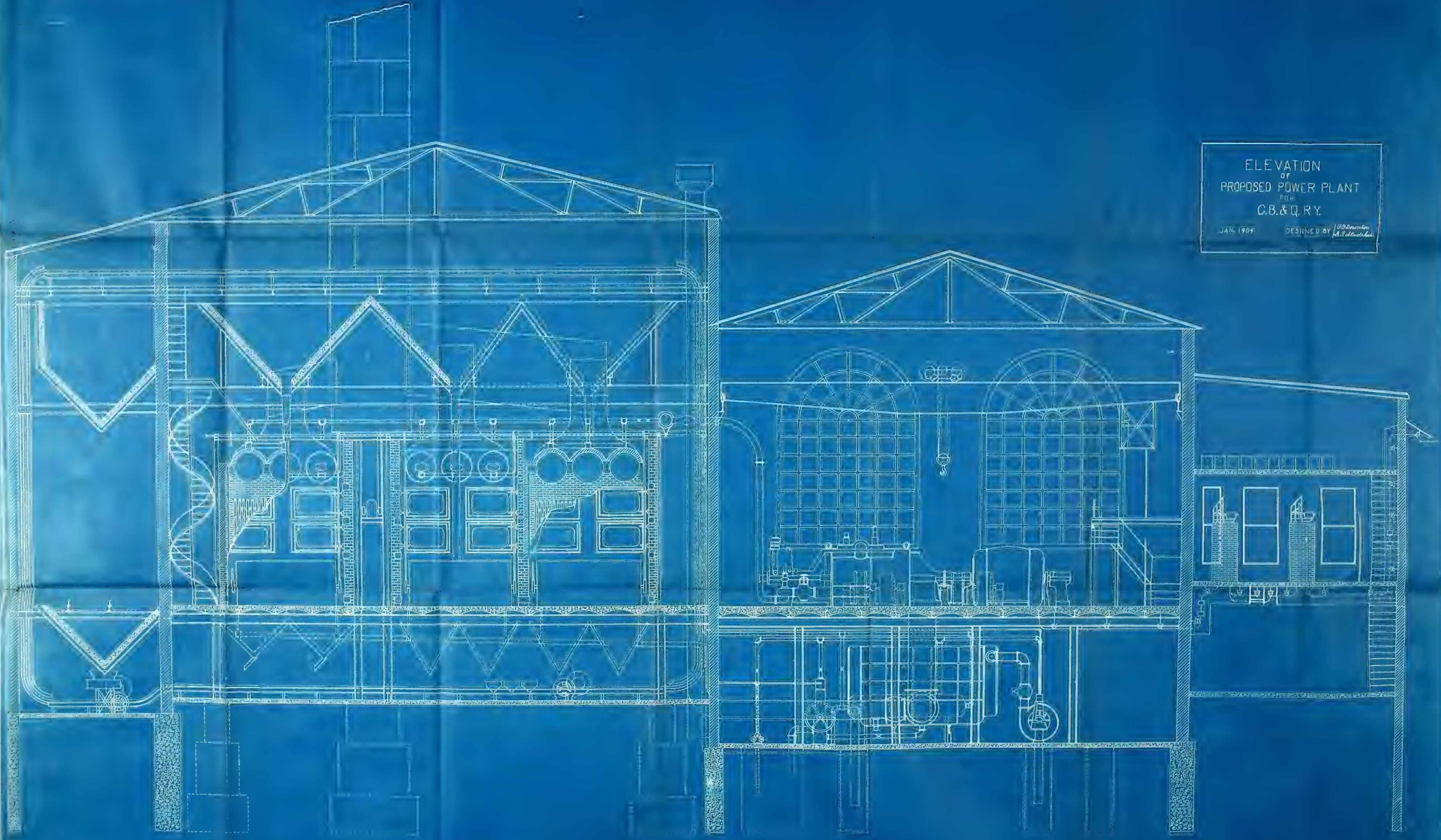
23

[illegible]
[illegible]
[illegible]



ELEVATION
OF
PROPOSED POWER PLANT
FOR
C.B.&Q. RY.

JAN. 1909 DESIGNED BY O. G. Downton
A. I. Studebaker

FIG. 23

PLAN
OF
SED POWER PLANT
FOR
C.B.&Q.RY.

9 [redacted] BY { G. I. Stadeker.
P. J. Bounton

SCALE ¼" = 1'

2-1

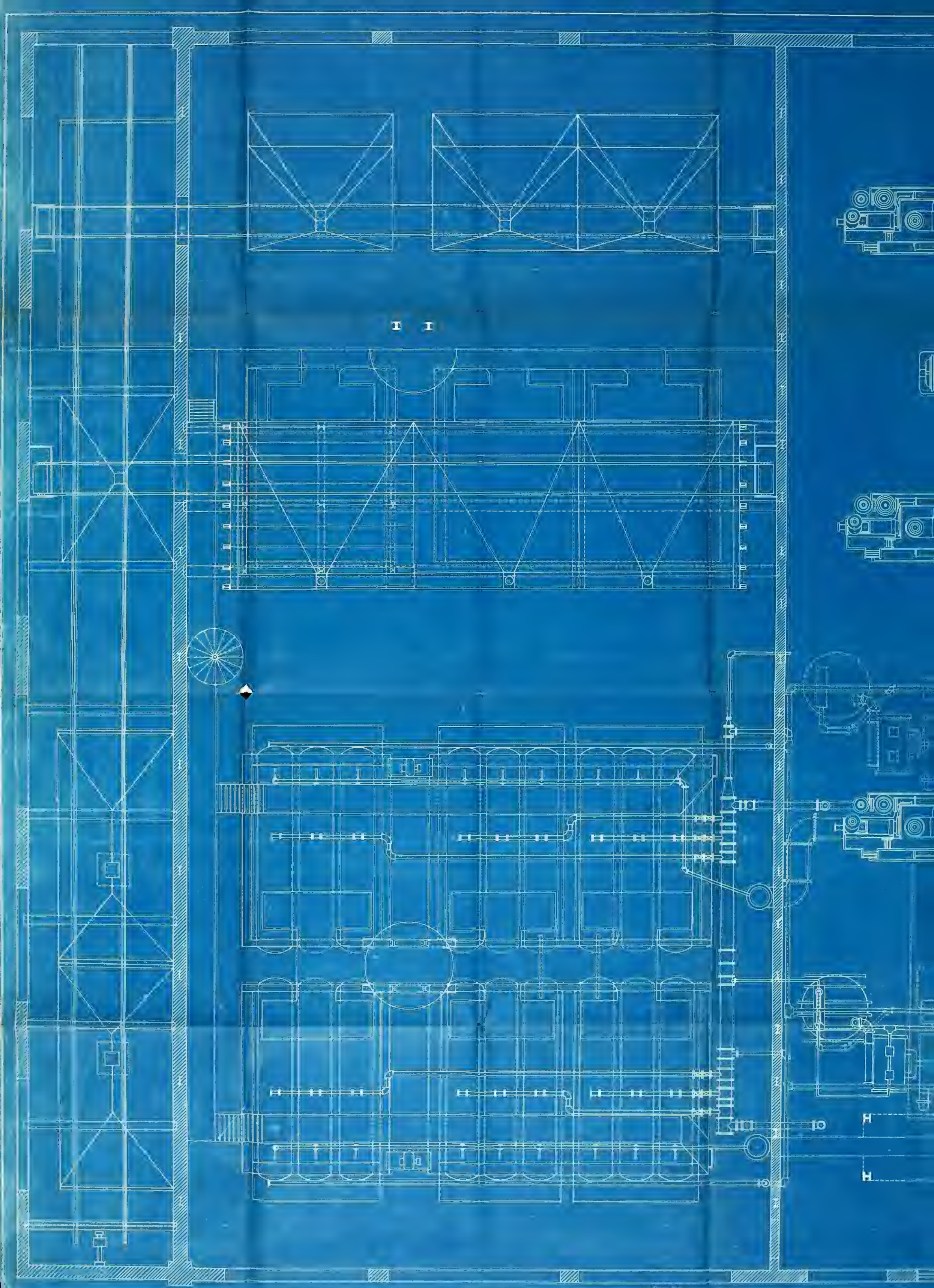
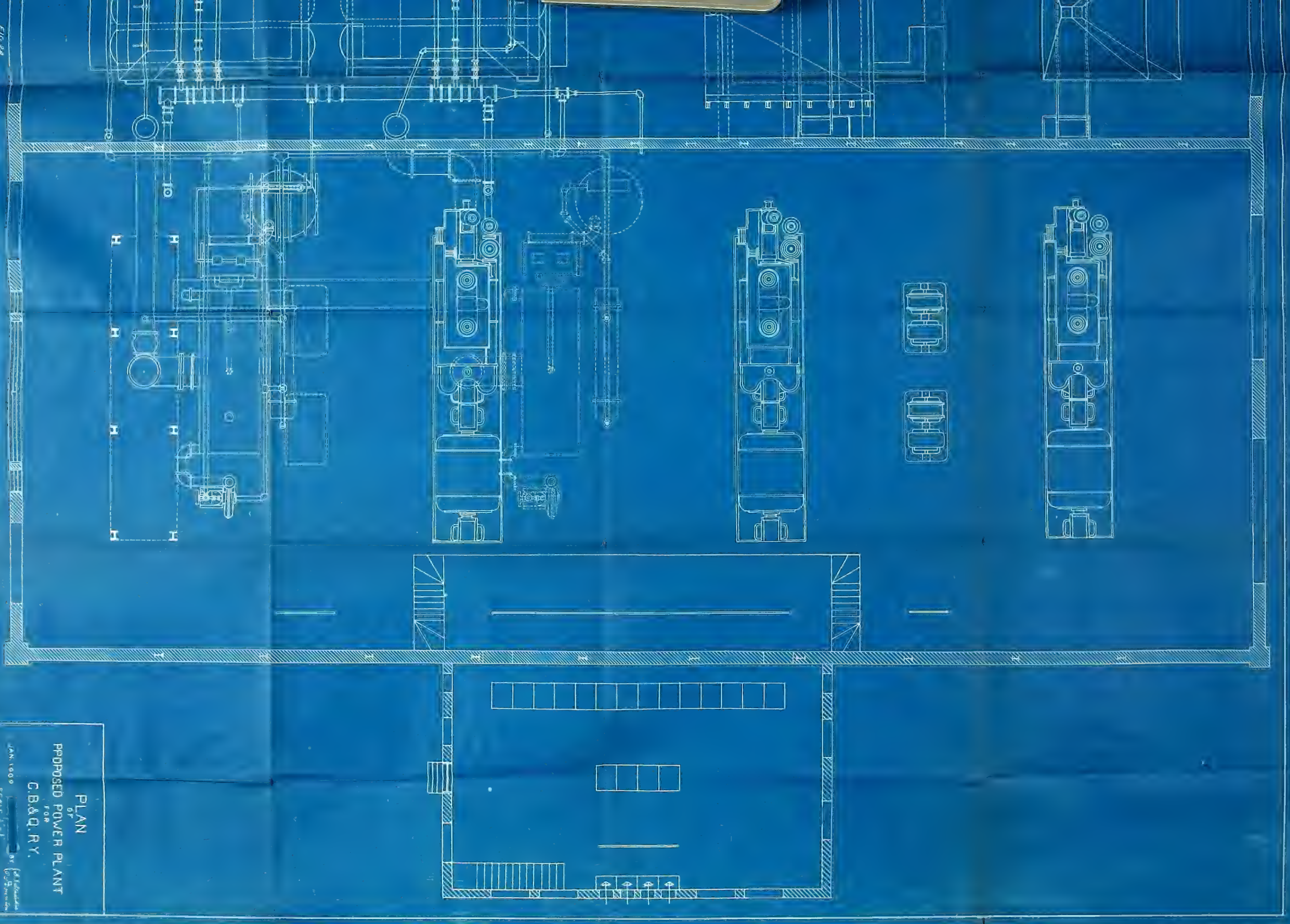


FIG. 24

FIG. 24



PLAN
OF
PROPOSED POWER PLANT
FOR
C.B.&Q.RY.

JAN. 1909

SCALE ¼" = 1'

BY

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY

[illegible]
INSTITUTE OF TECHNOLOGY
[illegible]

25

[illegible]
[illegible]
[illegible]

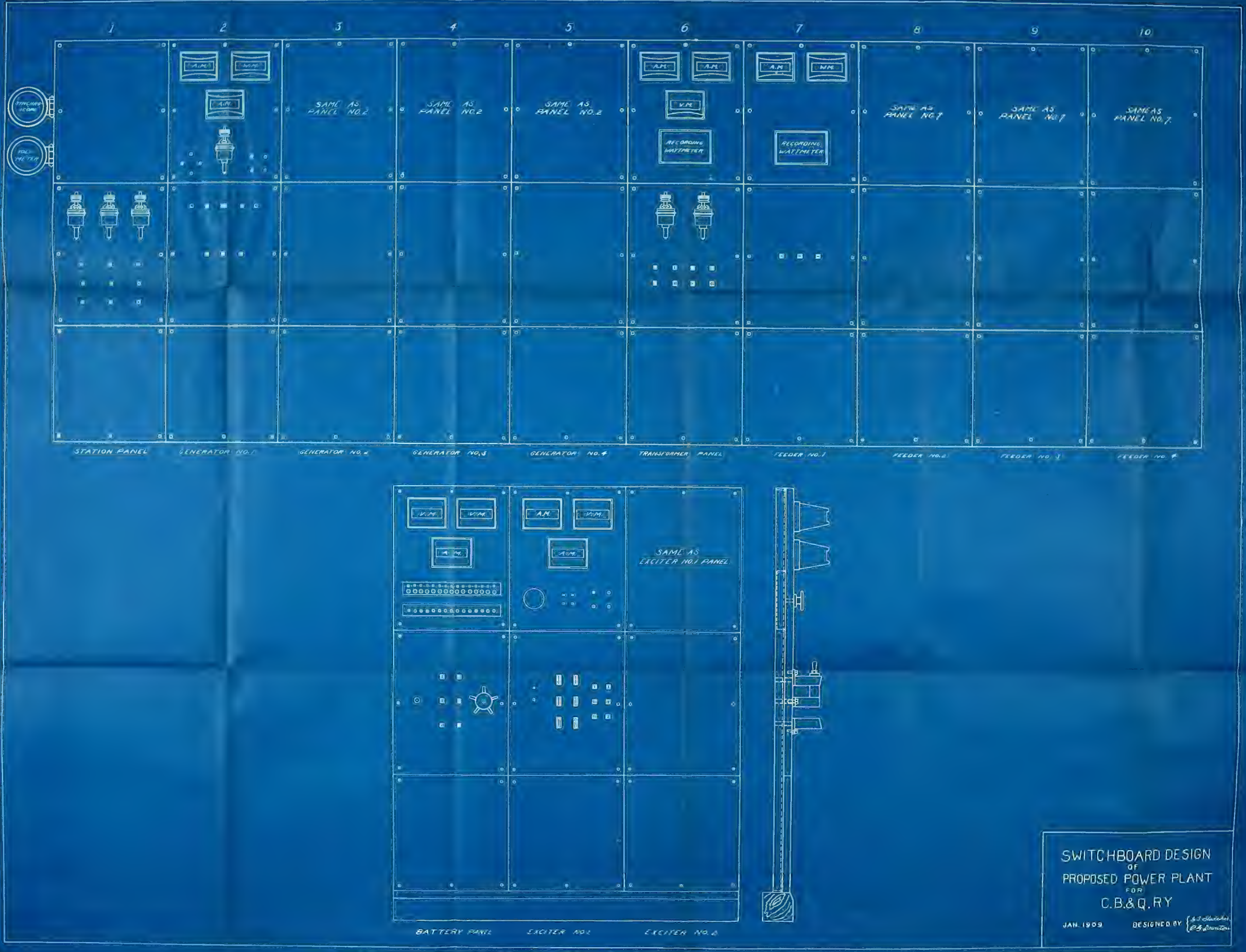
1
2
3
4
5
6
7
8
9
10
SYNCHRO-SCOPE
VOLT-METER
A.M.
W.M.
A.M.
SAME AS PANEL NO.2
SAME AS PANEL NO.2
SAME AS PANEL NO.2
A.M.
A.M.
V.M.
RECORDING WATTMETER
A.M.
W.M.
RECORDING WATTMETER
SAME AS PANEL NO.7
SAME AS PANEL NO.7
SAME AS PANEL NO.7
STATION PANEL
GENERATOR NO.1
GENERATOR NO.2
GENERATOR NO.3
GENERATOR NO.4
TRANSFORMER PANEL
FEEDER NO.1
FEEDER NO.2
FEEDER NO.3
FEEDER NO.4
V.M.
V.M.
A.M.
A.M.
V.M.
A.M.
SAME AS EXCITER NO.1 PANEL
BATTERY PANEL
EXCITER NO.1
EXCITER NO.2
SWITCHBOARD DESIGN
OF
PROPOSED POWER PLANT
FOR
C.B.&Q.RY
JAN. 1909
DESIGNED BY

FIG. 25

[illegible]
[illegible]
[illegible]

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2

ARMOUR
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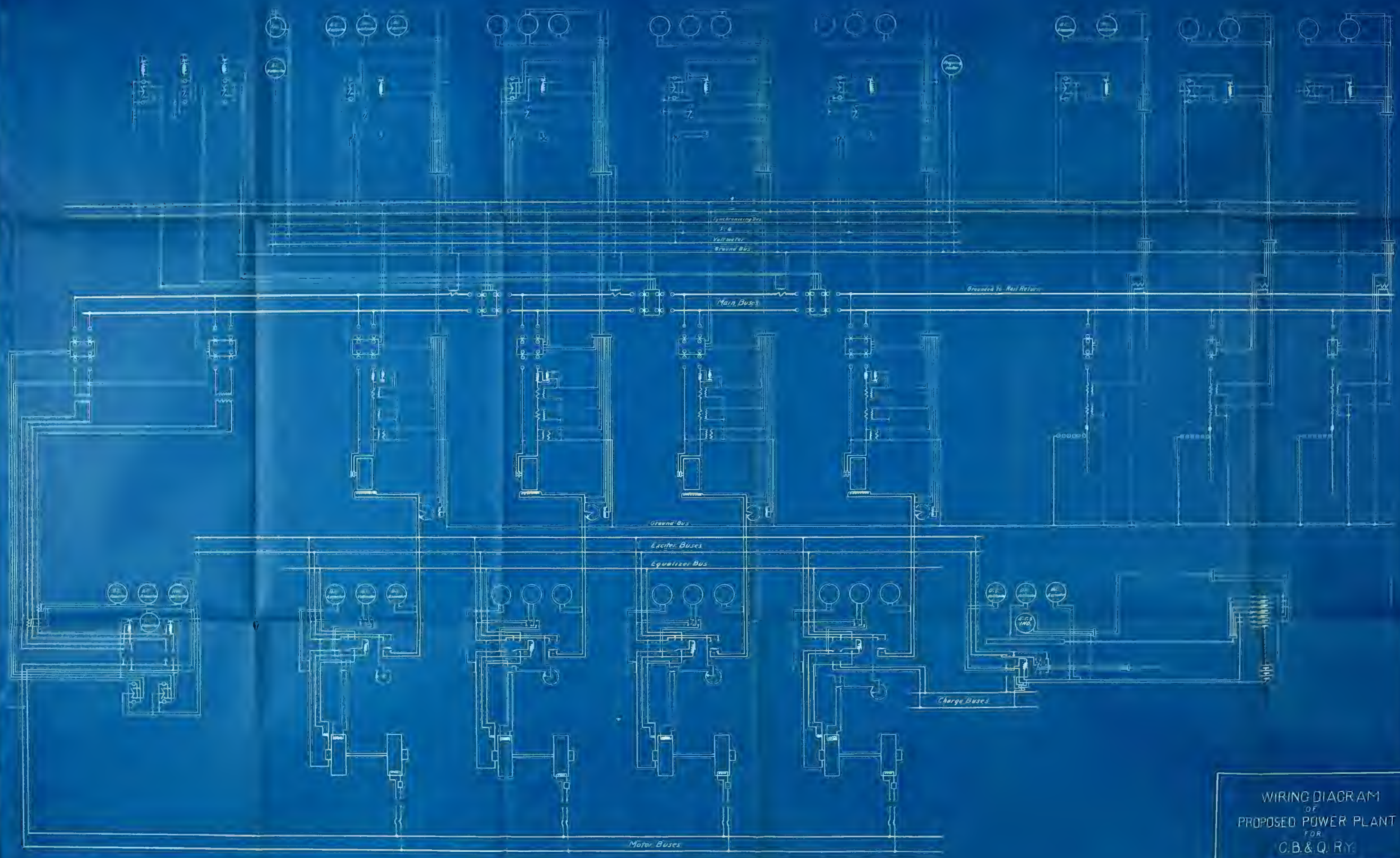
[illegible]



WIRING DIAGRAM
OF
PROPOSED POWER PLANT
FOR
C.B.&Q. RY.

JAN. 1909 DESIGNED BY { O. S. Downton / G. I. Stadeker

FIG. 26

[illegible]
[illegible] OF [illegible] TECHNOLOGY
[illegible]